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THE JULY SCIENTIFIC MONTHLY

Edited by

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NEW BOOKS OF SCIENTIFIC INTEREST

"Particles" of Modern Physics. J. D. STRANATHAN. Illustrated. xvi + 571 pp. $4.00. May, 1942. Blakiston.

This book has been written to serve two purposes. First, it is intended to convey to the student many of the essential fundamental concepts of modern physics. Second, to serve as a reference book for the more advanced student.

Physics. F. L. ROBESON. Illustrated. ix + 819 pp. $4.50. April 24, 1942. Macmillan.

The author intended this textbook to present the subject in such a fashion that it would not be necessary for the teacher to explain the text in order that his classroom time might be devoted to demonstrations, discussions, and the solution of problems. Elementary mathematics, repetition, and historical sidelights are employed.

From Copernicus to Einstein. H. REICHENBACH. 123 pp. $2.00. 1942. Alliance.

The author presents a history of scientific ideas and discoveries that led to the formulation of the theory of relativity. The story begins with the revolt of Copernicus against the Ptolemaic system and presents a development of his views of the world. It attempts to show the effect of electricity on the conception of space and time.

Photo-Micrography. R. M. ALLEN. Illustrated. viii + 365 pp. $5.50. 1941. Van Nostrand.

This is a handbook of microscopic photography the object of which is to explain every operation occurring in practical work. It tells how to use each type of standard equipment; how to improvise "homemade" devices when the standard apparatus is lacking; the technique involved. The text is accompanied by diagrams and numerous micrographs.

The Structure of Protoplasm. W. SEIFRIZ, ed. Illustrated. vii + 238 pp. $3.00. 1942. Iowa.

The theme of this symposium is that structure is the most significant property of living matter, and this monograph is intended to re-awaken in American botanists an interest in the study of protoplasmic and gel structure. This book is published by the American Society of Plant Physiologists and deals principally with present concepts.

Voles, Mice and Lemmings. C. EITON. Illustrated. 496 pp. $10.00. June 4, 1942. Oxford.

This book presents an ecological study of certain rodents. The first part surveys vole and mouse plagues. The second part describes the vole and mouse fluctuations that occur in Great Britain and Scandinavia. The third and fourth parts contain the history of fluctuations in Labrador and Ungava.

Representative North American Fresh-Water Fishes. J. T. NICHOLS. Illustrated. 128 pp. 1942. Macmillan.

This book comprises illustrations of sixty representative North American fresh-water fishes, each accompanied by a page of text. Such questions as the names of a fish's fins, the difference between pike and muskalonge, curious nesting habits are discussed and answered.

Introducing Australia. C. H. GRATTEN. Illustrated. xvi + 331 pp. 1942. John Day.

In this book Australia's history, politics, industry, agriculture, labor situation, and cultural life are outlined as well as its part in the two World Wars and its orientation in world affairs. The author believes that Americans are not well enough acquainted with Australia, and has written the book to enlighten them.

American Polynesia. E. H. BRYAN, JR. Illustrated. 208 pp. $1.50. 1941. Tongg.

The author first describes the coral islands of the central Pacific as a whole; their geography, topography, history, utilization, fauna, flora and native cultures. He then discusses a number of the islands separately and in greater detail, preceding each description with a map of the island under consideration.

The 1941 Year Book of Public Health. Ed. by J. C. GEIGER. Illustrated. 544 pp. 1941. Year Book Publishers. $3.00.

This book is intended for the health officer, the epidemiologist and the laboratory worker. It is a collection of articles that have appeared during the year in various medical journals, American and foreign, and is presented as a summary of the advances made during the year.

Introduction to Musicology. G. HAYDEN. xiii + 329 pp. $4.00. 1941. Prentice-Hall.

As the sub-title indicates, the aim of this volume is to present "a survey of the fields, systematic and historical, of musical knowledge and research." Under systematic musicology is discussed the relations to music of acoustics, physiology, psychology, aesthetics and pedagogy. Bibliographies and an index are included.

Educational Psychology. G. W. HARTMEN. Illustrated. xvi + 552 pp. $2.75. 1941. American Book.

This book is divided into three parts: The Psychological Approach to Educational Problems, the Improvement of the Organism and Its Functions and the Adaptation of Instruction to Developmental Levels. Bibliographies, charts and tables are included.

Psychological Effects of War. R. D. GILLESPIE. 251 pp. $2.75. 1942. Norton.

The purpose of this book is to present the lessons of those who have experienced modern war so that we may know what we have to meet and how to meet it. The author, an English psychiatrist now with the Royal Air Force, observes the psychological effects of warfare on the military and civilian population.

Rationed Rubber. W. HAYNES, E. A. HAUSER. Illustrated. vii + 181 pp. $1.75. June, 1942. Alfred A. Knopf.

This book is concerned with the rubber shortage in the United States and the steps being taken to correct the situation. Discussed are such subjects as synthetic rubber, the amount of wild rubber we may get from South America, and the value of reclaimed rubber.

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JULY, 1942

BACTERIAL WARFARE[1]

By COLONEL LEON A. FOX
MEDICAL CORPS, U. S. ARMY

BACTERIAL warfare is one of the recent scare-heads that we are being served by the pseudo-scientists who contribute to the flaming pages of the Sunday annexes syndicated over the nation's press. This question of bacterial warfare has been brought forward from time to time since World War I. The use of the organisms that cause communicable diseases as an instrument of warfare was considered by the Conference on the Limitation of Armaments held in Washington in 1922. An international commission consisting of Professors Pfeiffer (Breslau), Bordet (Pasteur Institute), Madsen (Copenhagen) and Cannon (Harvard), appointed at the time, reported to the League of Nations essentially as follows: (a) The effects of bacterial injury can not be limited or localized; (b) modern water purification methods protect against the organisms of typhoid and cholera; (c) plague is a disease that would be as dangerous for the force using the organisms as for the attacked; (d) the danger from typhus has been exaggerated; (e) modern sanitary methods are effective in controlling communicable diseases.

Following this pronouncement by these eminent scientists, the question of bacterial warfare suffered a lapse of interest; but during the past year, as an incident of the preparation for the Geneva Convention, there has been a marked revival of interest in this supposed bugbear, bacterial warfare. Possibly this is only a part of the effort of professional pacifists to add all the imaginary frightfulness they can picture to the known real horrors of war.

The space and thought that have been given to this question by feature writers have not been without effect and many people now believe that bacterial warfare represents a real threat and problem for future generations. Many are now associating chemical warfare and bacterial warfare, with the result that in the resolution of adjournment, voted by the General Commission of the Disarmament Conference on July 23, 1932, at Geneva, we find chemical, bacteriological and incendiary warfare grouped for consideration. The mere fact that this great body of peace workers considers bacterial warfare seriously enough to prohibit its use justifies military men in considering this agency of warfare. We know how little treaties protect, so we should study the question to see if the use of biologic weapons is a real problem for the military minds of the future.

Under biologics we include all those

[1] This article was written nearly ten years ago and appeared in military journals in several countries, and it will be reprinted in *The Military Surgeon* in the near future. The subject is timely and of much scientific interest.

organisms that may invade the body of man or animal to produce disease, so while we use the term bacterial warfare we do not limit this paper to a consideration of bacterial diseases. We will also consider the filterable viruses, Protozoa and other pathogenic forms, as well as their toxic products.

With the powers of the world in session at Geneva discussing the future of warfare, and with some of the great nations of the world recommending the complete abolition of chemical warfare, it may appear strange to have one consider biologic warfare. I believe all will agree that while it is a mistake to live in the past it is equally undesirable to ignore the lessons of the past in prognosticating regarding the future. It is therefore well, before we consider the possible use of biologics in warfare, to discuss briefly the question, Will the nations of the world abandon the use of chemicals as an instrument of warfare?

Every advance in thought or design meets reaction and antagonism from the minds of the previous generation. It does not take some radical departure from the accepted views of the day such as marked the revolutionary concept of Copernicus or Darwin to start all "as is" conservatives on a tirade of opposition with the usual tenor of their remarks: "It is against the law of nature," "It is against religion," "It conflicts with all known law," "Even if true, it does not fit into the existing order of things." A man of middle age to-day may remember the old mossback who refused to ride on the train of the nineteenth century. In fact the train and street car had not completely overcome all the pooh-poohs of the backward ignoramus until they were involved in a fight for their very existence with a newer means of transportation—the motor. The motor vehicle had just had time to have a proper road net constructed when this engine, becoming "air-minded," needs no roads. Have they been generally accepted? Certainly; however, remarks such as, "If God wished man to fly he would have given him wings," were made in the pulpits of this country during the present century.

It takes more than the harpings of the minds of yesterday to scotch the wheels of progress. It may startle many to talk of world progress in connection with implements of warfare. However, it is not believed that any fair-minded individual can deny the place in world advancement that is due to the spirit of conquest. The peaceful shepherd, content to watch his flocks, has added little to the world's knowledge. The trader and warrior have discovered and spread knowledge. Trader and warrior are almost inseparably associated throughout history, and slowly as they may have progressed, they usually lead the thought of the day. The spirit of adventure and discovery has always marched with the warrior. The discoveries of the warrior are not limited to implements of war; however, these are the factors we wish to consider. In this field again we meet the same antagonism at every advance that the fighting man has made an antagonism that has affected all minds of the "as is" type, including conservative and reactionary individuals. Every advance, every discovery of a new weapon by the fighting man, has had to overcome two groups of opponents: (1) The fixed and established military group that is always sure the new weapon "won't work," "Is not as good as older weapons," "Not practical," etc. (2) The pacifist group—the shepherd group that considers each new weapon more terrible than the former and cries out against it.

Primitive man in his combats certainly had no weapons. Are there any to-day that believe that this early creature did not fight over "food and females"? It may be added that all combat ultimately resolves itself in the final analysis to a

strife for one of these basic biologic requirements—nourishment or sex. Fighting over gods was a later development; and these fights over gods were over a personal god, a god of the land or tribe, a god to favor their own special country, a benevolent god who would make their country a more bountiful place to live.

In the early combats man could only bite and claw and choke an adversary. This was the day of brute strength. Cleverness had relatively little value. The first man to use a weapon was the man with the best mind of his day. The first weapon used must have been very simple and elementary. Possibly a hard object held in the hand with which he brained his opponent. This weapon possibly did not create much comment. This was not an age of comment; however, the descendants of the type that could not learn to use this weapon are not numerous. Has this weapon been abandoned? Certainly not; it is an excellent weapon, and no good weapon has ever been discarded. Its use to-day is very limited because of discovery of other weapons of greater range and effectiveness.

Development of weapons has always been for the purpose of using intelligence to overcome mere physical force. The factor of range, killing an opponent before he can close with you, is a most important factor when the man of intelligence must meet superior physical force or number. Probably the first weapon to provide range was a club, possibly a sharp stick, the forerunner of the iron-tipped spear. The club may have had a stone head attached. These weapons not only advanced the clever man over the mere strong man; they aided man in his fight with the man-eating animals of the time. However, if we can make deductions from the early cave records of men of this period, advance was slow because the intelligence was of such low order that they were slow to understand and accept these new weapons. The race improved because the thinker, the successful warrior lived and won the females and left descendants; the slow and reactionary type did not live to reproduce. With every advance in weapons man is giving evidence of a desire to overcome brute strength by means of a weapon with range and effectiveness.

We can picture the introduction of the early propelled instruments, such as the arrow, causing a storm of opposition. Some youngster designed some form of propelling instrument for a sharp stick and possibly suffered the jeers of the snaggled tooth elders as he shot the sticks into inanimate targets, and only received the reward of complete recognition when he shot a sharp stick through the belly of an old pack leader to take over a band of cowed females. The progeny of this genius were of a higher order of mentality and possibly soon learned the value of organization, with the result that a tribe of arrow users developed. This seemed like the final advance, and who can doubt their ability to inflict their will on the men of the time?

The fact that the conquered men, possibly of superior physical development, considered the weapon a cruel and brutal implement that God had not endowed man with did not cause it to fall into disuse. The only thing that caused this weapon to fall into disuse and finally be practically abandoned was the development of such protection as caused the implement to cease to be effective or because other instruments were designed of greater range and effectiveness. These factors are the only things that have ever caused a weapon used successfully to be abandoned.

The outcry against the use of chemicals seems to people of this day to be quite a serious factor, and some wonder if their use will be curtailed by this influence. The following factors should

be considered before we make a decision: (a) No effective weapon once introduced has ever been abandoned until it was displaced by a more effective weapon or protection developed that rendered the instrument useless. (b) The hue and cry that attended the introduction of chemicals is not unusual on the introduction of a new weapon. The early use of gunpowder produced a reaction in every respect similar to the cry of the present-day pacifist against gas. Will the use of chemicals in warfare be abandoned? Probably not. Will the use of chemicals be curtailed? Certainly; just as certain as the race progresses, just as certain as new and more effective weapons are designed—not before this advance is made.

Will the next advance in warfare see the use of biologics? Will the next agent used be the living organisms, bacterial warfare, the scourge of armies from the most ancient times—the communicable diseases? The question of biologic warfare will be considered in more detail because here again we run into the most elaborate and fanciful statements.

A review of military history will reveal the great influence that disease has played in past wars. Results have been decisively influenced in many campaigns by epidemics of communicable disease. In some campaigns they have caused such tremendous losses and such great numbers of non-effectives that the combat has reached a stalemate. However, in certain instances, for unknown reasons, there has been a great difference in the degree to which combatants have reacted to the epidemic conditions. In a few cases we are able to understand why the communicable diseases appeared to have greater invasive power toward one of the armies; in other instances we do not understand clearly why there was a difference in the degree of involvement of the forces.

Volumes have been written on the epidemic diseases that have attacked the military forces. We will not attempt to review this extensive literature, but the doctor, especially the epidemiologist, knows that the student of history who reads only of tactics and strategy, the victories and defeats of a campaign, without familiarity with the medical history of the war, is likely to give some commander credit for success or failure that all too often has been caused by some epidemic of communicable disease. This is not meant to depreciate military success, for the great general is often a great sanitarian, and even Alexander may owe a part of his success to his doctor, philosopher, teacher—Aristotle's advice to "boil his water and bury his dung."

We must remember that we can march through the pages of military history all the way to the twentieth century before we come to a campaign where the missiles of the enemy produce more casualties than epidemic disease. In most of the ancient campaigns of any duration some one of the great military plagues did more to decimate the military forces than all the man-made munitions. I say one advisedly, although often many infections raged and famine and scurvy accompanied the communicable diseases.

What was the nature of these ancient pests? Were they diseases of that age now no longer known? No, the military pests that existed then are still with us. The Big Six of all time (war times) are: (1) The enteric fevers, typhoid and the paratyphoids; (2) the dysenteries; (3) cholera; (4) typhus; (5) the plague, bubonic plague, the Black Death; (6) smallpox.

Do not consider for a moment that the above diseases had any monopoly on the right to destroy armies. It is probable that at times influenza and the epidemic pneumonias took such heavy toll that but little fuel was left to be consumed by the Big Six. Again, under conditions where malaria is endemic, this disease is second to none in the production of non-

effectives in military ranks. In fact measles and epidemic meningitis may well be added to the list of military scourges.

This paper is not for the purpose of considering the epidemic conditions of the armies of the past, but it is realized that many individuals will naturally consider that if these infectious agents were able to produce such frightful outbreaks of disease by the simple process of chance infection under natural conditions, then in the hands of man, as a military weapon, they may well prove even more destructive. They may fail to consider the fact that the same measures that are now so efficacious against the chance infections occurring in nature may prove of equal value in combating the same agency of destruction when used by man.

We have presented biologic warfare in all its horrors; now let us analyze the problem in detail. What agents can be used to produce death and disease? How can these agents be introduced into the bodies of the enemy? We will discuss these questions in the order stated. The biologic agents available for warfare are: (1) The communicable diseases; (2) other infective processes (such as wound infections); (3) toxic products of bacteria.

The communicable diseases are well known. They are the so-called transmissible diseases that produce epidemics. They are caused by a living contagion and are spread from man to man or animal to man by various channels of transmission. All the Big Six and the other diseases mentioned above belong to this group.

The second group, the other infective processes that are available, include such infective materials as the agents that infect wounds; gas gangrene, tetanus, anthrax and other wound contaminations that are infectious but not communicable.

The last group of dangerous agents are the toxic products of bacterial growth. We will mention but a single terror-inspiring example—botulinus toxin. A portion of this toxin almost inconceivably small when introduced into the body by any channel is lethal. We will give details later.

No one will question the effectiveness of all of these agents in producing casualties when introduced into the bodies of unprotected and non-immunized individuals. The important question then is how? How are these agents to be introduced into the bodies of the enemy to produce casualties?

Any consideration of the deliberate use of pathogenic organisms as a means of warfare will have to consider the question of how to produce a destructive epidemic in the forces of an opponent and at the same time protect one's own forces from invasion by the virulent organisms in question. Certainly at the present time we know of no disease-producing microorganisms that will respect uniform or insignia, and the use of bacteria in warfare for the destruction of opposing forces will have to be predicated upon the successful prior immunization or the complete isolation of the forces employing the disease-producing organisms through some system of quarantine.

Any intelligent discussion of bacterial warfare must certainly give detailed consideration to the question of how the living contagion is to be introduced into the individuals that are to be infected. We can well begin this investigation by a study of the channels of infection. The communicable diseases may be classified on the basis of their "routes of transmission." By this is meant the path that the living contagion follows when it leaves the body of the sick man or animal, or in some cases the carrier, to enter the body of the susceptible host to produce disease. On this basis we

may classify the communicable diseases into intestinal diseases, respiratory diseases, direct contact diseases, and insect-transmitted diseases.

The intestinal diseases are produced when some small portion, usually a microscopic portion, of the material from the intestinal canal of the sick man with its living microorganism, is introduced into the alimentary canal of the susceptible individual. Typhoid, cholera, and dysentery are well-known examples of this type of disease.

The respiratory diseases, sometimes known as "sputa borne" or even "air borne" diseases, are the communicable diseases spread by the transmission of living microorganisms from the respiratory tract of the sick to the respiratory tract of the invaded. This group of diseases is of tremendous importance and embraces such conditions as the common cold, influenza, pneumonia, diphtheria, epidemic meningitis, smallpox, and possibly of special importance for war purposes, the pneumonic form of bubonic plague.

The group of diseases that we refer to as "insect-transmitted" are those where the invasion of the new host is effected by the bites of insects which have previously fed on an individual—man or animal—infected with the disease in question. A period of incubation on the part of the insect between feedings on sick and feedings on individuals to be infected is necessary in certain instances; with other diseases such interval is not required. Examples of insect-transmitted diseases that require an interval for the development of the contagion within the body of the insect after feeding on the infected individual are malaria and yellow fever, both transmitted by mosquitoes. Bubonic plague, a disease of rats that is transmitted to man by the bite of the rat flea, does not require an incubationary period for the rat flea to develop infectiveness.

The venereal diseases are direct contact diseases. They are of profound military importance and have proved decisive factors in certain past wars, notably influencing the European campaigns of the fifteenth and sixteenth centuries. The deliberate use, however, of this means of injury is fraught with difficulties when we plan a method of securing personnel to effect the necessary exposure. The soldier's danger from the venereal diseases will not come from the open, avowed wartime enemy who loves him least, but from the money-loving or uniform-worshipping ladies who profess to love him most. Therefore, while these diseases may at times exceed all other causes of military non-effectiveness, we can dismiss them without further discussion while we are considering bacterial warfare.

It follows, then, that the communicable diseases that constitute an epidemic or pandemic threat to the military forces are the intestinal, respiratory, and insect-transmitted diseases.

The Intestinal Diseases

Mankind is all too familiar with the terrible epidemics of typhoid, cholera, dysentery and the diarrheal conditions that have destroyed military forces in the past. However, it is highly questionable if this group of diseases will ever in the future cause any such terrible catastrophes, for the reason that the epidemiology of these infections is so thoroughly understood that modern sanitary methods and immunization processes have rendered comparatively innocuous these hazards of earlier armies.

The deliberate use in warfare of these agents, however, we shall consider. While occasional small outbreaks of these diseases may be due to food infections, real epidemics of this group of diseases are traceable only to infected water and milk supplies, or to such a complete sanitary breakdown that general fecal contamina-

tion of food supplies occurs. The possibility of contaminating a milk supply presents practically insurmountable difficulties, although it is theoretically possible that spies might use such a means to discommode and harass civil populations. Of course, it has no practical application to the military forces themselves.

Contamination of water supplies of civilian communities by means of infection of large reservoirs and storage basins where the water is held awaiting consumption, is a possibility. Contamination, to be effective, would have to be subsequent to treatment by the modern water purification plant consisting of filtration and chlorination, or of course it would be valueless; but this is within the range of possibilities, and it is possible that future wars will reveal that spies will make an effort to contaminate municipal water supplies.

The use of the intestinal group of diseases against forces in the field would probably prove entirely ineffective because modern water purification methods and the close supervision of the water supply that is accepted as a necessary incident of military service will absolutely preclude the successful employment of this means of combat.

In considering the intestinal group it may be well to stress the fact that the reason modern armies, and for that matter all civilized communities, do not have serious epidemics of these diseases is not because the infective agents that cause these diseases are not present or available, but because modern sanitation protects the personnel.

Let us take a typical example, typhoid fever. The incidence of typhoid in our civil population has been greatly reduced during the present century. Let no one think, however, that this is due to any scarcity of the typhoid bacillus, and it must also be remembered that the civil population has not had any general immunization such as helps to protect the Army. Typhoid has not retreated to the outskirts of civilization; it is all about us. Every state, yes, every county in the Union, is infected. Typhoid carriers in the United States possibly number 100,000 and are generally without supervision. The reason we have only about 5,000 deaths from typhoid fever per year in the United States of America instead of about 100,000 deaths is because the great mass of our people now use water that has been rendered safe by filtration and chlorination. They consume milk that has been pasteurized and other foods that have been protected.

The same statement may be made concerning the low incidence of the dysenteries in our country. The infection is present, but epidemics do not occur because our sanitary measures are effective. We need not fear infection from without with this group of diseases; we are already grossly contaminated.

The die-hards will say that cholera is not so easily handled and is not at present a problem in America. Granted. We do not have cholera in the States; but our Army and our people do live in the presence of cholera without having epidemics of the disease. The Philippine Islands, where our Army maintains an effective fighting force entirely free from this terrible scourge, has a carrier incidence of the vibrio that causes cholera that is always high. The intestinal group of diseases will certainly not prove destructive against any civilized nation that cares to pay the price of the protection that modern sanitary methods provide.

The Respiratory Diseases

In leaving the intestinal group of diseases we proceed from the problem that represents the greatest triumph in preventive medicine to the group of diseases that baffles the best efforts of all health workers. In the control of the intestinal diseases we have so much to be proud of.

In preventing the respiratory diseases we have accomplished so little. This is stated with a full knowledge of the wonderful results that have been obtained with smallpox vaccination, and the immunization to diphtheria by the use of toxin products, as well as with a full realization of the fact that we are on the threshold of equally great accomplishments in controlling scarlet fever.

It should be noted that these great accomplishments are not sanitary triumphs such as glorify our work with the intestinal group of diseases, but immunization processes. Not being able to prevent the infection reaching mankind, we take advantage of the fact that familiarity with the organism, while not breeding contempt, does produce immunity. Therefore we use the only method that appears to offer any great protection against the respiratory diseases in nature, namely, immunization. It must be admitted that health workers can accomplish practically nothing in the way of protecting peoples from infection with the great host of respiratory invaders, and such protection as we have is due to either the natural or artificial exposure to these organisms.

In this group of diseases we find a number of maladies that are serious enough to be effective war weapons if ways of using them can be devised. However, before proceeding we should call attention to the fact that in this group are also a large number of diseases that are not suited for military purposes. For instance, smallpox, while a very serious epidemic disease, must be dismissed immediately. All military forces are immunized to this dreadful scourge, and we can therefore dismiss it from further consideration.

Many of the diseases of childhood, while constituting a military problem at time of mobilizing rural recruits, are not suitable for military purposes for the reason that the factor of age susceptibility plays so much importance when we consider the entire group that comprises our population. As an example we may mention diphtheria. While in childhood a very high percentage of the population is susceptible to this disease, the great majority of these same individuals develop considerable natural immunity to the organism that causes diphtheria without further interference than the normal aging. Therefore, while we see epidemics of diphtheria in schools and orphanages, we do not encounter serious outbreaks involving large numbers of any adult population. This disease is cited only as an example wherein the factor of age susceptibility is important; there are a number of diseases that show this phenomenon and would therefore be unsuited as offensive military weapons.

Certain diseases, such as influenza, pneumonia and the common cold, do not show a marked tendency to limit their injury to any one age group and would be efficacious if they could be used against military personnel. Mankind is as helpless to-day as at any period in history in the control of these diseases; also they are very serious conditions that produce great numbers of non-effectives, and in the instance of the epidemic pneumonia they result in a tremendous mortality.

Before we surrender to the individuals who threaten such frightful havoc with this group, we may well ask how they are going to start an epidemic of influenza, pneumonia or the common cold. If they answer that they will introduce the germs that cause these diseases we can well laugh at them. The process is not so simple. The factors that make respiratory epidemics are not so elementary. They include not only the infection of the individual, but the question of the resistance of the infected animal. The organisms that cause these diseases are all about us. They are always with us. Epidemics mean more than simply infec-

tion; they mean the rapid transfer from individual to individual of these infective agents. They mean a lapse in the immunity of the invaded, and possibly something else.

I do not know of a bacteriologist or an epidemiologist who can tell you how to start a respiratory epidemic unless the stage is especially set. I know many who are certain that whenever you place a large group of individuals, man or beast, under poor hygienic conditions, with overcrowding, poor ventilation, and exposure to unfavorable climatic conditions, or other factors that decrease resistance, respiratory outbreaks will occur in spite of any precautions that can be taken, and that if large numbers of highly susceptible individuals (rural populations) are present the outbreak can be expected to assume epidemic proportions.

It is also worthy of note that when epidemic conditions prevail certain organisms may possibly have greater invasive power, for then apparently populations that were not so susceptible or readily invaded may be attacked when they previously escaped injury. It will be noted that as in the case of the intestinal diseases, so with the respiratory diseases it is not a simple case of introducing infection that constitutes a menace. The organisms that produce most of these diseases are always with us, and epidemics mean more than infection. While we can not understand exactly how epidemics start, and we question the ability of a military agency deliberately to produce an epidemic of one of these diseases, we feel certain that if bacterial warfare is ever contemplated they will not think of using the respiratory group of invaders for the reason that quarantine, isolation, and all other methods to control diseases such as influenza, are practically valueless. The torch once set off might destroy friend and foe alike, and would therefore prove of no value as a military weapon.

The two diseases in this group that are most frequently mentioned are influenza and epidemic meningitis (cerebrospinal fever), possibly because of their importance during World War I. All that has been stated above applies with especial force to influenza, where in addition to the fact that no one knows how to control this disease, we must add that we are not even positive about the actual organism that causes the condition. Epidemic meningitis, on the other hand, is a very definite, specific disease due to a very well-known organism. We must admit at the outset that this is a very serious disease, and that it often assumes epidemic proportions in military organizations. However, if we stop to consider the nature of the organism and the epidemiology we see how entirely unsuited epidemic meningitis is for use as a military weapon. The organism, the micrococcus of Weichselbaum, is so delicate that even on the most favorable culture media it rapidly dies when exposed for even a few hours to temperatures much below that of blood heat. This disease is spread by carriers, and the organism must be introduced almost directly from the nasal pharynx of the carrier to the respiratory mucous membrane of the individual invaded or it will be destroyed by the unfavorable temperature conditions while en route.

Those individuals who think this disease may be used for military purposes will answer that carriers in the forms of prisoners, etc., would be introduced into the opposing forces. To those who know anything about epidemic meningitis this suggestion is ridiculous. Any military aggregation of any great size already has so many carriers present (anywhere from 2 to 30 per cent.) that the introduction of a few more or less is of no moment. Epidemics of meningitis occur only when *overcrowding* is associated with conditions that lower the general resistance, as exposure, unfavorable climatic conditions, and fatigue. Meningitis is, and

probably always will be, a military problem; but the individual's friends and associates, not the enemy, are the great problem with this disease.

We will not take up in detail all the various respiratory diseases. The tabulation would prove tiresome, for the story would always be not so much a question of the great danger of the introduction of the infective agent, but the creation of epidemic conditions, a soil in which the organism could produce an epidemic, overcrowding, and lessened resistance.

The Insect-transmitted Diseases

These diseases will probably most certainly influence wars of the future as they have in the past. An invasion of such a country as Mexico, at the present time, could constitute more of a sanitary than a military problem. With malaria, dengue, and possibly even yellow fever along the seaboards, and typhus endemic in the plateau district, our main problems would be sanitary. Bubonic plague might also be encountered here as well as in any other place. This disease, bubonic plague, is the disease entity that many consider best suited for military purposes. To begin with, it is a frightfully serious malady, a decimating disease that has most profoundly influenced warfare in the past. It is possible that the rise of the Mohammedan world was due to a great extent to the fact that Europe was in the throes of the greatest scourge mankind has known, the plague, at the time that Mohammed's followers were ready to organize and extend the influence of the crescent until the horns were about to encircle the Mediterranean. Certainly these Arabian tribesmen had never shown any signs of military greatness or valor prior to this period, and it is probable that their religious ardor would have met with small success against the well-organized nations of the time if these nations had not been practically exsanguinated by the "Black Death."

The use of bubonic plague to-day against a field force, when the forces are actually in contact, is unthinkable for the simple reason that the epidemic could not be controlled. Infected personnel captured would provide the spark to set off possible outbreaks of pneumonic plague in the ranks of the captors. Infected rats would also visit and spread the condition. An advance over terrain infected with plague-bearing rats would be dangerous. Therefore, except as a last desperate, despairing hope of a rapidly retreating army, the use of plague by forces in the field is not to be considered.

The use of plague to harass civil populations presents less difficulty than the use of the organisms against a field force. Those who think that plague will be used as an offensive weapon consider that civil communities may be infected by introducing plague-infected rats. Of course this is easier to state than to accomplish, but it may be possible for airplanes flying low to drop recently infected rats. At least this is the statement that the individuals make who consider the use of this weapon feasible. Even with so terrible a pandemic disease as plague, however, there is a great deal more to the question of epidemics than mere infection. For instance, to cite an example, one that Gill so forcibly states, "Not half a dozen cases of plague occurred amongst Europeans (including British troops) stationed in the Punjab during the year 1924, when about 500,000, or one fortieth of the indigenous population suffered from the disease."[2] If these intelligent people were able to avoid the infection when residing in an environment that was literally infiltrated with the infection, it certainly should be possible to control bubonic plague in a population such as we have.

[2] C. A. Gill, "The Genesis of Epidemics." London: Baillière, Tindall and Cox, 1928.

For that matter, the question of plague is not a condition that takes us to the outskirts of civilization. Our own Pacific Seaboard became infected in 1900, and following the San Francisco earthquake the infection extended and is now more or less endemic as a rodent disease involving not only rats but ground squirrels. Here again it is not a question of can we control the infection; we are controlling it, and have not had an outbreak of human plague of sufficient size to designate as an epidemic.

The other insect-transmitted disease that is most frequently assigned a place of importance as an agent suited for warfare is typhus. This disease is certainly terrible enough to satisfy even those individuals who are anxious to preach the gospel of frightfulness. The military and civil populations that have been destroyed by typhus bear witness to how effective this agent of destruction can be. However, again we have a condition that is easily controlled. Complete solution of the problem of endemic typhus is not yet in print, although it is probable that the work of such men as Dyer, Maxcy and Zinsser will soon offer a complete explanation of how this scourge simmers along during the interepidemic periods. Epidemic typhus is thoroughly understood. The epidemiology is so simple that it can be embraced in the name of the transmitting insect, the body louse. The control of epidemic typhus is the simple question of the control of louse infestation. Of course quarantine will help to prevent the introduction of the infection, but quarantine is futile if the Army is allowed to become lousy. The lousy Army may become the victim of typhus, even in America, without the introduction of infection from extraneous sources. The weight of opinion in the best epidemiological minds is that, as Maxcy suggested, endemic typhus is probably carried over between epidemics in a rodent reservoir. Endemic cases occasionally occur when transmitted to man by an insect, and when the infection is passed from man to man by the body louse, with the resulting enhancement of virulence, epidemics may be expected to result.

The difficulty of starting an epidemic of malaria, yellow fever or trypanosomiasis (sleeping sickness) appears to be obvious, for no one has suggested the use of these agents. Those who understand the epidemiology of these diseases know they are not suited for war purposes even though they realize the problem they present to military forces in endemic areas.

This completes consideration of the communicable diseases. We have discussed in some detail practically all except the direct contact group. The only diseases of this group of great military importance are venereal, and we have given our reasons for dismissing this group from consideration.

The Infective Processes

Certain disease processes that affect the tissues are caused by living organisms and are therefore designated as infective, even though they are not considered communicable in the sense that they tend to be transmitted from man to man. These disease processes include such infections as tetanus, gas gangrene, anthrax and the ordinary pyogenic (pus formers) invaders. The agents that produce these infections have all been mentioned as possible war weapons, and it must be admitted that so far as the first three are concerned, with some scientific judgments on the part of their sponsors.

The agents that cause tetanus, gas gangrene and anthrax are not delicate organisms such as the relatively short-lived, easily destroyed pathogens that cause most of the communicable diseases. They are very resistant, spore-forming organisms, generally capable of a pro-

longed period of viability without loss of virulence, even when separated from the animal tissues. It is not surprising, therefore, to find one of this group (anthrax) selected as the infectious agent best suited for military purposes by a science student preparing an undergraduate thesis on "Bacteriologic Warfare."[3]

The selection of anthrax does credit to his training: in fact the entire study shows more intelligent thought than any article that has come to the attention of the writer. His description of the characteristics of the proposed bacterial invader are worth quoting:

> What shall we say are the requirements for a perfect military pathogen? It attacks preferably both man and animals. It must be quick-acting, highly virulent, and capable of causing disease in small quantities. It must be highly resistant, capable of surviving outside the body under the most adverse conditions, and even resisting partial cooking or a careless attempt at sterilization (a spore former). The causative organism should be able to force its entrance through all the avenues of infection; respiratory tract, alimentary tract, and breaks in the skin. The disease should not be too actively contagious, and it must be very well understood, for pathogens should never be used without contemplating the possibility of their getting out of control. Finally, and perhaps most importantly, it should be possible to obtain large quantities of the pathogen in virulent strain and spore form with the least possible manipulation and delay.

After this excellent description of the perfect hypothetical agent, he selects anthrax as the agent best suited to meet the requirements of a bacterial weapon. I can not agree with Pentler that "Anthrax satisfies the requirements almost perfectly"; but I believe all bacteriologists will agree that he has selected the agent that most nearly meets the requirements he has so well outlined.

These spore-forming invaders are a real problem. Tetanus and gas gangrene are pathogenic processes that have always been associated with gunshot wounds and are therefore of special interest to the military surgeon. They do not produce epidemic diseases, however, and they are not communicable. They have to have a portal of entry made for them, a wound, and while the use of these organisms to contaminate battlefields might cause an increase in the number of cases of tetanus and gas gangrene, they would not increase the number of casualties. They would only complicate the treatment of those already disabled. It might be added that we have an entirely satisfactory serologic prophylactic agent for tetanus, and that as a result of the surgical advances of the last fifty years, gas gangrene is less frequent than in the pre-bacteriologic days.

We can not dismiss anthrax so readily; however, it is worthy of note that although anthrax is almost a world-wide disease, nevertheless anthrax infection of gunshot wounds is practically unknown. If gross contamination of battlefields with the organism of anthrax is effected it is granted that cases of anthrax infection of wounds will occur, and possibly some few cases of infection in individuals who have not been wounded; but when we consider that human epidemic anthrax is unknown during the bacteriologic era, I question if we need fear greater danger from this organism than contamination of wounds.

It will be noted that up to this point we have not discussed the technical difficulties that a military force would have in contaminating a hostile force. The difficulties in the case of the communicable diseases are so obvious that they need not be mentioned. The epidemiologic factors make the communicable diseases unsuited for offensive military use. The causative organisms are all either short-lived when separated from the living tissues or else readily destroyed by ordinary routine sanitary precautions.

[3] C. F. Pentler, "Some Thoughts on Bacteriologic Warfare." Massachusetts Institute of Technology, Department of Biology and Public Health.

We can not make this statement concerning the highly resistant infections such as tetanus, gas gangrene and anthrax. These agents are admittedly the most dangerous; but it must be remembered that to be dangerous they must be alive, and that many technical difficulties present themselves when living agents are to be used that are not present when missiles and chemicals are used. Shells can be used to project missiles and chemicals on to an enemy many miles distant; but bacteria can not be used in this way. No living organism will withstand the temperature generated by an exploding artillery shell. Airplanes may contaminate terrain, but their effect would be quite local and probably less dangerous and less certain than high explosives used in the same way.

It is not maintained that bacterial contamination is impossible. A retreating enemy may hurriedly contaminate the terrain that is to be evacuated. However, it is believed that the use of living organisms in offensive warfare presents technical difficulties that are not generally considered. The contamination that spies and other individuals could effect, using the only really effective agents we have mentioned—the highly resistant, spore-forming organisms that are so dangerous to wounds—would prove too local to be of any value whatsoever.

Toxic Products

The forms of bacterial warfare include not only the possible distribution of living organisms in the force of an enemy but the possible use of toxic products derived from bacteria. Certain of our bacterial toxins are the most deadly poisons known. The toxin of the bacillus botulinus is so powerful that instances have been recorded where toxins have been produced so toxic that .005 milligram would kill a 250-gram guinea pig. This material, botulinus toxin, is poison for man. It is possibly the most toxic agent known, and will produce the lethal effect in any way that the material is introduced into the animal. If consumed with food, injected into the tissues or even dropped on the mucous membrane or conjunctiva, it is equally deadly.

This must be the material referred to when we read such dramatic statements as the following: "An airplane can carry sufficient toxins to destroy an entire city." Such statements have an element of truth in them. In fact they are conservative. An airplane could carry enough of the botulinus toxin to destroy every living man in the world *if* administration of the toxin was as simple a process as production and transportation.

There were over one hundred billion bullets manufactured during the World War—enough to kill the entire world population fifty times; but a few of us are still alive. It is easy to calculate the lethal (fatal) dose of a toxic agent; but do not think it is so easy to figure on the casualty-producing power of a military weapon.

The hostile aviator will not be received with a welcome, nor can he expect to land at an air field near any large city and find the entire population lined up ready to accept the carefully measured lethal dose of botulinus toxin.

The release of tremendous quantities of botulinus toxin over a large city may produce human casualties; however, the extent of the damage might be only the wholesale destruction of rodents, sparrows and possibly numerous cats and dogs—not such a serious loss in time of war. It is difficult to evaluate properly the possible effects of the bacterial toxins. Certainly such statements as an airplane destroying an entire city with toxins is ridiculous; but they may have a value comparable to chemical agents, with this great disadvantage, however: bacterial toxins are readily destroyed by heat; therefore, like bacteria, they are unsuited for use in shells.

Animal Diseases

The use of living organisms to produce disease in live stock, such as horses and mules needed for transportation of Army equipment and supplies, has been mentioned as a possible form of bacterial warfare. It is believed that the difficulties here are quite similar to those mentioned for diseases attacking man, with this great advantage to the defense that the veterinary officer will have in controlling epidemics. The veterinary officer can destroy any animal or group that he considers a menace to the health of the animals in the Army. The medical officer can not take such steps to control epidemics that threaten human populations.

If we expand the term bacterial warfare to embrace such phases of biologic warfare as will include the agriculture pests, then an additional factor to consider is the fact that spies and possibly hostile aviators might inoculate growing crops with such pests as the boll weevil, the corn borer, the Mediterranean fruit-fly and like destructive agents. These agents in most instances, however, take so long to invade sufficient terrain to be effective in destroying crops that their value in actually overcoming the resistance of a foe is questionable. They take several years to advance over a large area, and might prove an economic problem years after the war has been completed; therefore, they violate one of the fundamental ideas in warfare, since they would interfere with the ability of the conquered nation to pay the victors for the beating they had received.

Conclusions

It is believed that it has been shown that the development of implements of warfare represents an evolution based on the gradual application of the improving mind of man. The one factor of importance in this development has been effectiveness. It has been a question of the good mind versus the strong back; of the thinker versus the lifter. It is believed that the future of warfare will be based on the same principles. It is therefore apparent that the question of whether chemical munitions will be used or not and whether bacterial warfare will be used or not will depend on their practicability rather than on the sentimental reactions of pacifists.

I consider that it is highly questionable if biologic agents are suited for warfare. Certainly at the present time practically insurmountable technical difficulties prevent the use of biologic agents as effective weapons of warfare.

AN ANTHROPOLOGIST IN MODERN RUSSIA

By Dr. A. HRDLIČKA

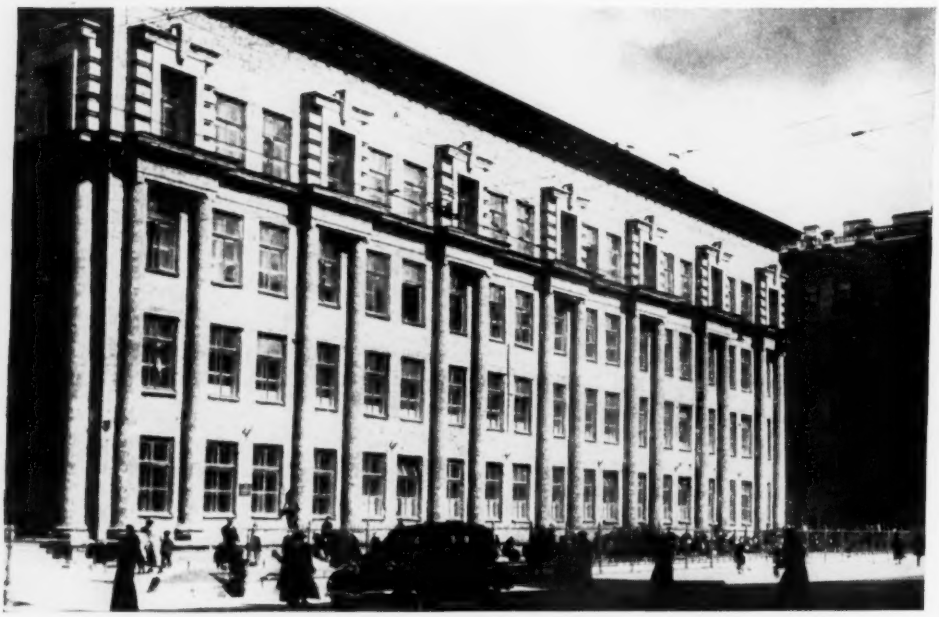
UNTIL APRIL, CURATOR OF PHYSICAL ANTHROPOLOGY, U. S. NATIONAL MUSEUM

THE last trip, in 1939, and a necessary "cap" to the Alaskan explorations. Must see in England and elsewhere the late discoveries of early human remains, and then the Siberian skeletal materials in the Russian museums, for comparison with those of our Alaskan explorations.

Leave New York, April 15, on the *S.S. Aquitania*, one of the largest and best of the transoceanic steamers, in seemingly full health and not even tired; and the trip is uneventful until two days before arrival when, on the top deck, due to an unexpected roll of the boat, twist body and sprain or tear something in the chest, under the lower part of the sternum, which results in more or less continued raw pain in that locality. From that time on lose appetite, can not walk as much as used to on decks, and can not sleep well. The next morning fairly easy, but aggravate condition by playing shuffleboard on a wet deck—every shove rouses more the severe pain under the sternum, until I have to give up. Reach London, nevertheless, though somewhat strenuously, and next day spend whole forenoon in slowly walking from place to place and attending to things; but in the afternoon condition aggravates, can not rest any more in any position, slight feverishness—evidently something more than ordinary, and so must get help. Walk rather painfully to the University Hospital, which I saw last night when looking over the anatomical department of the university where in a few days I was to give some lectures—

ON A SUNNY AFTERNOON ON ONE OF THE NEW STREETS OF LENINGRAD

MOST OF THE CITY IS GRADUALLY BEING REBUILT WITH SUCH STRUCTURES AS THAT ON THE LEFT.



ONE OF THE NEW RUSSIAN HIGH SCHOOLS IN LENINGRAD

THESE ARE ENTIRELY MODERN INSTITUTIONS. THE CLASSROOMS, DECORATED WITH PICTURES AND FLOWERS, PRESENT A VERY CHEERFUL ATMOSPHERE.

they hurry me to a bed, diagnose coronary thrombosis, and the next six weeks have to spend in the hospital—the first vacation of my life, under the best possible care, with more friendliness than I deserved and in conditions for which I never can be enough thankful.

But the tasks called and so, after giving in London two of the lectures, which did me good, and seeing the important Palestine remains, which furnish the "missing links" between present man and the Neanderthalers, left on June 3 on the Russian boat *Sibir*[1] for Leningrad. And from that time on was with the Russians, who almost killed me with their kindness. In Leningrad, one of the most outstanding cities of the world, could still not walk more than a few blocks at a time, and that very slowly; but as long as needed they sent every morning a car for me, and took me home again at night, facilitated my work in every way, and provided care by their foremost specialist in heart troubles. And I kept on very slowly but steadily getting stronger, until it was possible to undertake the trip to Siberia, and there even to make three little field expeditions.

A more formal brief report on the trip to the Soviet Union was published in the "Exploration Volume" of the Smithsonian for that year and need not be repeated; but much could be said of a more general nature. I have this time, however, not kept a journal, due partly to still weakened condition and partly to the overwhelming amount of what I saw and heard. Having been in the country twice before, in 1909 and in 1912, I was able to note to some extent what happened to it and what was now going on, and will put down a few of the outstanding impressions. These are not colored with any "ideology," for I am an inborn democratic individual.

[1] Since then turned into a hospital ship, and as such sunk on August 19, 1941, by German bombers, with the loss of 400 wounded, women and children.

In 1912, shortly before the World War, Russia was a typically bureaucratic, military and antiquated-church country, with some admirable museums and institutions, but in general subdeveloped industrially, with much poverty and with a mass of good but retarded population. A very large majority of the people lived in drab villages, were over 70 per cent. illiterate and in the vast country worked, as well as lived, in a more or less primitive fashion. The war of 1914–17, the revolution in 1917 and the civil war of 1918–23, blighted and damaged most of the cities, and largely destroyed the railroads and other utilities. The scars of all that were still visible now, in 1939, but vast changes have taken place since 1923 in many things. Leningrad and Moscow have more than doubled in population and have widely extended territorially. Leningrad towards the southeast, especially, is becoming a great Russian-type metropolis; while Moscow is being largely rebuilt according to plans that appear almost fantastic, and is already in every way one of the greatest of modern cities. There is a steady destruction of the ugly or what is in the way, and restoration of the worthwhile, with much solid and characteristic new construction. Cities all over, in fact, have become largely industrialized; the drab old villages are being changed into attractive small towns. Everywhere one sees the building of new schools, clubs, theaters, movies, hospitals. The old hospitals, still numerous, are not all that could be desired, but are generally well furnished and their defects are being corrected; the new ones are all that medicine could wish for. There are numerous large and smaller new hotels, well built and furnished, even though the plumbing and sewage in some of them in the provincial towns are not yet perfect. Life everywhere is humming, the people are in a mental ferment, illiteracy is largely gone, there is a striving in all directions, and a gen-

CHARACTERISTIC DAILY SCENE IN ANY OF THE MANY RUSSIAN MUSEUMS
IN ALL THE MUSEUMS THERE ARE DEMONSTRATORS, MOSTLY WOMEN, WHO TAKE GROUP UPON GROUP OF VISITORS THROUGH THE COLLECTIONS, EXPLAINING EVERYTHING OF NOTE.

IN THE "PALACE OF THE PIONEERS"
THE "PIONEERS" ARE SIMILAR TO BOY AND GIRL SCOUTS IN THIS COUNTRY AND IN ENGLAND.

IN A "REST HOME" FOR SCIENTISTS
RUSSIA IS AHEAD OF US IN THIS RESPECT.

eral hunger for knowledge. Every one appears to be working, reading, meeting, discussing. Radio is everywhere, even on the top of corner houses in the large cities, in the cars on first-class trains and in the villages. Deep under Moscow is the finest subway in existence, with stations that are truly like underground palaces. There are modern street cars, buses, electricity not only in the cities but also already in many of the villages. And there is no end of other matters of interest to a visitor.

For the anthropologist, however, the subject of main concern are the humans, and here, too, there was witnessed a great deal. Saw, even in faraway Siberian villages, clean cheerful nurseries and kindergartens; groups upon groups of sunburnt tots with their woman guardians roaming like so many near-naked sprites through woods and along banks of streams or pools. Older children, fittingly dressed, with red ties, are the boy and girl scouts; and of the still older ones and young adults, the "physculture" youth, one sees whole large columns of them, marching, exercising, singing, on squares and broad streets, after work hours, to music furnished without pay by bands of workers. The whole population seems to have been rejuvenated, old people to have largely vanished. To see a bewhiskered man in the cities, and even in much of the country, was not far from as much of a rarity as to see a horse in our capital. Even the drinking habits have changed, the old vodka being largely replaced by soda waters and beer. And there is any amount of ice cream being sold on the streets of the cities. The military are everywhere, but they are unobtrusive, just strolling about, visiting museums, galleries, theaters, without weapons. As to policemen, in my three weeks in Moscow, not counting the one guard before every legation, in all my roamings I saw but two. Though I went wherever I wanted, never once had I been stopped,

THE CHILDREN OF RUSSIA IN THE COUNTRY AND CITY

Top left: CHILDREN IN A GARDEN. AS THE PEOPLE HAVE BEEN ESSENTIALLY AGRICULTURAL FROM TIME IMMEMORIAL, THE CHILDREN ARE NEVER HAPPIER THAN WHEN IN THE FIELDS OR GARDEN. *Top center:* ONE MEETS MANY SUCH GROUPS OF TOTS IN THE FIELDS AND WOODS EVERYWHERE ON A NICE SUMMER DAY. *Top right:* A CLASS IN EMBROIDERY. THERE IS MUCH FOLK ART IN ALL PARTS OF RUSSIA. *Bottom:* THE DIRECTOR OF THE FIRST TRADE SCHOOL AT A PLANT IN MOSCOW SHOWING STUDENTS THE TURNING LATHE SHOP WHERE THEY ARE TO WORK.

or followed, or even ogled, though my clothes must have shown that I was a foreigner. There were formalities to attend to with the passport, but no others. I saw many poorly furnished stores, still many old and gloomy yard houses, and only simply clad people; but little or no dirt, no disorder, no idlers on street corners, and but very few and that secretive beggars. The service in some of the hotels was slow and not very apt, but the food was plentiful, though at first when

I came there was a shortage of vegetables.

The museums, libraries, the many theaters, and the numerous movie houses, were invariably full to capacity. The thirst for reading was such that the newspapers and printers of popular books could not catch up with the demand. They publish both journals and books in vast editions, yet even these were seldom sufficient. One morning I wanted to get a newspaper. On the other

A FINE RUSSIAN TYPE

THE PEOPLE ARE GREAT LOVERS OF FLOWERS; THE WRITER, SOMEWHAT TO HIS EMBARRASSMENT, RECEIVED AN ARMFUL WHEN HE WAS LEAVING MOSCOW AND AGAIN WHEN LEAVING RUSSIA.

side of the square facing the Metropole Hotel where I stayed was a kiosk where the paper could be bought. To these kiosks a car would bring so many copies every few hours, and there was always a long line of people waiting for the delivery. When I came over that morning I counted 132 in front of me, and before I could get near the stand the papers were all gone. There are no yellow papers, nor yellow, lurid or loose literature.

Many of the people one met in the large cities reminded one of a sound country girl who suddenly was transplanted to city conditions and did not quite know as yet how to walk in them—but was fast learning. And, though there was no display anywhere of riches, I saw no slums comparable to those in other countries.

The museums I found, for the most part, in excellent condition, and the others being restored. One does not readily take to the numerous white-on-red slogans in the museums, nor the slow old service in some of them, or the tea-habits during office hours; but could not help but admire much that had already been accomplished by the young staffs and their eager interest in their work.

In general, I saw a new human world in the current of its formation, with remnants of the past still hanging to it like the pieces of last year's bark on a fruit tree, but with the renewed tree already bursting into flower and promising a great harvest. And while I did not understand some of the propaganda, I saw much wisdom in many things and an accelerating crystallization of a new existence, virile, generous, successful, and of a highly promising ultimate service to humankind in general.

Let us leave Russia to its own evolution. This is not and can not be our, American, evolution, for our past as well as present, our conditions and the nature of our people are different. We too can evolve, and are evolving; but as they learn our best from us, may we also tolerantly and in a friendly way observe and perhaps learn from here and there what is done and reached by them, as well as by other striving human groups in other parts of the world.

The trip to and through parts of Siberia was a revelation. Since 1912 everything has changed so that I could recognize but little more than the forests.

A YOUNG WOMAN WHO HAS LEARNED TO OPERATE A FIELD TRACTOR

THERE ARE MANY THOUSANDS OF SUCH WOMEN IN RUSSIA WHO LIBERATED THE MEN FOR WAR; ACCORDING TO SOME TESTIMONY, THEY ARE PROVING VERY EFFICIENT. WOMEN TAKE PART IN INDUSTRIES OF ALL SORTS, MUCH MORE SO THAN IN OTHER COUNTRIES.

RUSSIAN TYPES OF THE PRESENT DAY

AN OFFICER WHO PARTICIPATED IN THE FIGHTING WITH THE JAPANESE AT LAKE KHASAN IS TELLING OF HIS EXPERIENCES TO THE MEN AND WOMEN OF A LENINGRAD INDUSTRIAL ESTABLISHMENT.

A GROUP OF YOUNGSTERS FROM A MOSCOW TRADE SCHOOL
THESE BOYS HAVE CHARACTERISTIC YOUNG RUSSIAN FACES. NOTE THE FINE DENTURES.

The cities have grown greatly and become industrialized, while the country—vast parts of it—is turning agricultural, a repetititon of the story of our West since the nineties of the last century—a new world in the midst of its formation.

And an endless procession of trains with soldiers, cannon, ammunition, even some whole steel river boats, with now and then a crowded train of immigrants, all proceeding eastward. It was the time of the little war with Japan, and Siberia was pouring its armed forces towards the Pacific. In Irkutsk, my stopping place, and especially in its environments, there were many soldiers, though there was no excitement and everything went on normally. The city had suffered much during the late wars. Its fine former museum and library were gone, but the contents, I found later, or at least much of them, lie preserved in the vaults beneath an old church and will see daylight again when there is a new museum, which is in contemplation. Some day, and that not far off, when the mighty swift Angara that surrounds the larger portion of the city, is harnessed and gives its tremendous power, Irkutsk will become one of the most important Siberian centers.

Irkutsk, moreover, lies in a region which is one of the richest for human prehistory. Along the rivers of this beautiful region men lived from the upper paleolithic time and especially during the neolithic period, leaving behind many of their cultural remains, and also their skeletons. And the neolithic skulls and skeletons, of which already a large series has been recovered and are preserved in the present pro-museum, have shown themselves to be of exceeding importance for the study of Asiatic-American ancient connections: they are very close to those of certain types of the American Indian.

Due to the kindness of the head of the local university, the head of the temporary museum and the local scientists, I was not only able to see and utilize all the locally preserved collections, including those in the vaults, but I was able to make three trips along the Angara River and participate in some remarkably careful excavations carried on in the old sites along the river by Professor Okladnikov and his wife, who were from Leningrad. My everlasting gratefulness to all these friendly people.

During my observations over the

Soviet Union, I became deeply impressed with its anthropological opportunities. It would be of the utmost value to the science of man if it would follow and bring to light the physical as well as other changes which under the new form of life, with its culture, sanitation, better nourishment, care of the child and universal physical exercise of the youth, must be taking place. And it would further be most desirable to study the results of the intermarriages which are taking place on a great scale between the many nationalities composing the population.

On return to Moscow, much strengthened, gave two conferences at the Museum—one, for a wonder, in Russian. It must have been a mighty lame Russian; but they claimed they understood. This lecture was on "The Future Museum of Man" in Moscow. Also gave a demonstration of our cast making.

And then, with regret, had to leave, for the skies over Europe were heavily clouding. . . .

A strange thing. Before I came I had a notion that I would find everything different in social conditions—and I did not—not in the human essentials. What differs more or less are the views on matters, and the ways of doings; and even these are still largely in the process of crystallization. I wanted foremost of all to learn what really is, in Russia, a "communist"—searched for a definition or at least a brief description, and failed to get it. What I heard and saw was hard to believe, and I hardly dare to say it lest I might appear biased or deluded.

SEVERAL ASPECTS OF THE LIFE OF CHILDREN IN RUSSIA

Top left: PHYSICAL CULTURE GROUPS. *Top right:* A LITTLE BAND OF SMALL CHILDREN, TANNED AND HEALTHY FROM MUCH OUTDOOR LIFE. NO COUNTRY TAKES GREATER CARE OF ITS YOUNG PROGENY THAN DOES THE SOVIET UNION OF THE PRESENT DAY. *Bottom left:* THESE COUNTRY BOYS LIKE FISHING AS DO BOYS EVERYWHERE—AND THEY CATCH ABOUT EQUALLY AS "BIG ONES"! *Bottom right:* YOUNGSTERS BRINGING BIRD HOUSES INTO THE WOODS.

A CLASS IN BOTANY AT A RUSSIAN AGRICULTURAL INSTITUTE
THE DEMONSTRATION EQUIPMENT OF PLASTIC MODELS AND FRAMED PRESSED SPECIMENS OF PLANTS ARE MUCH LIKE THOSE USED IN AMERICAN SCHOOLS TO-DAY.

It seems that by far not everybody is or ever can become "one of the Party"; that the requirements are outstanding character and achievements; and that his or her main duty is to use and further develop these qualities for the benefit of what they call their "family" and we call our country. And they are developing and using them, until in some ways they have already outstripped most other peoples. I saw the results and could not but give credit. A line of these, which I had the occasion to test personally and found most grateful, were the excellent forest-park "rest-homes" for scientists. Even we as yet have nothing of this nature.

It was all confusing; and when a co-passenger on the return trip asked me "What is a communist?" I could only answer "I do not quite know." Wonder if anybody else does, outside of Russia. Our variety, it is plain, is something quite different. . . .

A question asked by many on the way out and at my return, was "How did they treat you?" to which I could only answer that, so long as they did not know where I came from, they did not "treat me at all," I was left completely to my own ways; but that as soon as I said anywhere I was an American, they did me such favors until it shamed me. In all my travels in Russia on this as well as the former two trips, I can say with all sincerity that I have never heard a single word against America; again and again the Russians said, "We have but two enemies in the world, one in the west and one in the east." As to America, they thought we did not understand them; and they constantly gauged their industrial and other achievements with ours—with much respect for ours. . . .

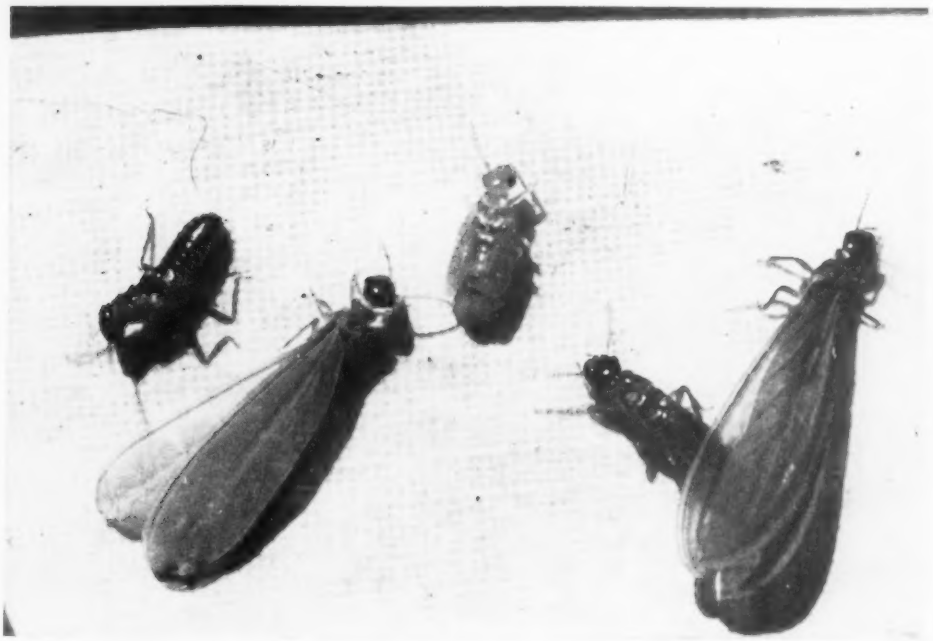
NATURAL HISTORY OF TERMITES

II. THEIR SOCIAL ORGANIZATION

By Dr. VICTOR W. VON HAGEN

FELLOW OF THE ZOOLOGICAL SOCIETY OF LONDON; SANTA MONICA, CALIFORNIA

ALL termite colonies, without exception, begin with a pair of male and female termites who have de-alated (unwinged) themselves by snapping off their four wings at a humeral suture at the base of the wing. Emerging from the darkness of their nests, the winged termites take to the air, not to swarm as does the bee or wasp (for fecundation does not take place in the air), but more as a form of dispersal for the incipient colony. From a termite colony of, say, a hypothetical 300,000 individuals, a third of this population are the winged caste. Normally, in the dark nests, they, like the other termite castes, flee from light; but during the swarm or dispersal, they have a reversal of these instincts. Upon gaining egress to the open, an instinct is developed to move toward the light. Any one having had a residence in the tropics will remember on the nights of the first rains



THE ALATES—THE REPRODUCING FACTORS OF TERMITES

IN THE TERMITE COLONY THE WORKERS AND SOLDIERS ARE USUALLY STERILE. REPRODUCTION IS CARRIED ON BY FERTILE CASTES, BOTH MALE AND FEMALE. THOSE WITH THE WINGS HAVE SWARMED; THE SMALLER DARKER FORMS HAVE DE-ALATED THEMSELVES, LEAVING ONLY SMALL STUMPS WHERE THE WINGS WERE ATTACHED. THE WHITE FORM IN THE CENTER IS BRACHYPTEROUS. IT NEVER LEAVES THE NEST, AND THE WINGS NEVER ARE DEVELOPED. THESE FORMS BECOME SUPPLEMENTARY QUEENS, MAKING COLONY BUDDING POSSIBLE WITHOUT SWARMING.

the myriads of winged termites flying about light-bathed areas forming a vortex of gyrating insects. Of this hypothetical 100,000 of swarming termites, but a fraction live to begin a new colony; birds, frogs, lizards, snakes, ants, insectivorous mammals and even man instinctively and knowingly come to the parts where the winged termite is emerging and consume them eagerly.

As soon as they have dispersed themselves, the winged termites fall to the ground and pair off. The de-alated female termite then lifts her abdomen, emits an attractive chemical odor that attracts the male, which places its labium to the base of the abdomen of the "fairer sex," and follows after the female in an intricate and thoroughly bewildering movement, the male remaining so close to the odoriferous anal parts of the female, it seems as if they are actually attached.

After this thoroughly exhausting tandem, the two termites, male and female, set off together, enter some cranny—a part of an old log or under the bark of a tree—and there mate and begin a new colony, the impregnated female laying within a relatively short time eggs which develop into neuter workers and soldiers.

This curious phase of the termite's biology—the institution of the colony by a single pair of reproductives, the so-called "king" and "queen"—has been termed "gynandrarchic," as each colony is composed of both sexes, which is diametrically opposed to the institution of colonies of the other social insects,

THE EGG-LAYING "MACHINE" WHICH IS THE QUEEN TERMITE

IN THE HARD SECTION OF THE TERMITARY IS A SPECIALLY CONSTRUCTED CELL INTO WHICH LEADS A LABYRINTH OF RUNWAYS. THIS IS WHERE THE REPRODUCTIVE IS HELD. AMONG THE *Nasutitermes* THERE IS USUALLY A SINGLE QUEEN WHICH OFTEN EXCEEDS THE WORKERS AND THE SOLDIERS BY AS MUCH AS TWENTY TIMES. THIS REMARKABLE PHOTOGRAPH SHOWS A QUEEN 25 MM. IN LENGTH BEING HELPED BY THE WORKERS INTO ANOTHER SECTION OF THE NEST. SUCH A REPRODUCTIVE WILL LAY AS MUCH AS THREE TO FIVE THOUSAND EGGS IN A SINGLE TWENTY-FOUR HOURS.

notably the bee, wasp and ant. These hymenopterous colonies are strictly matriarchic; the male insect remains a mere episode in the life of the colony. After the female ant, for example, is fecundated, she retires alone to begin the colony without the aid of the male, who dies almost immediately after the sexual act. The impregnated female is provided with a small muscular spermatheca, or sac, for the retention of the spermatozon which was filled by the male during mating and is never renewed. The female probably has the ability to close and open this sperma-sac at will, allowing her to lay fertilized or unfertilized eggs. With the exception of the manner of reproduction, there is rather close similarity between the social structure of the ant and termite. It is really an extraordinary thing to find in nature two organisms so immensely distant in their ancestral origins and physical structures which have hit upon identical methods of elaborating a social organization, and in these two colonies we see the extraordinary phenomena of convergent evolution.

Meanwhile within the incipient termite colony, the first eggs are developing into workers: the small, delicate, transparent nymphs, as they are called, are capable of movement on hatching. Nourishment is taken from the female reproductive by ingesting the fecal contents from her anus. The growth of the worker caste, although discontinuous, is fairly rapid. By moulting or sloughing off its integument, which is a lightly pigmented exoskeleton, growth is accelerated by the insect, which increases in size with each moult.

After the final moult, when the insect reaches what is termed its "last instar," the worker takes command, if one can use such an anthropomorphic designation for the worker's activities during the expanding of the colony. It enlarges the

THE *NASUTITERMES* "QUEEN" REMOVED FROM ITS NEST WITH ITS WORKERS AND PARASITES. PLAINLY VISIBLE ON THE QUEEN'S BODY IN THE CENTER OF THE PICTURE IS A TERMITOPHILE, WHICH IS A DEGENERATED STAPHYLINID BEETLE THAT LIVES IN TERMITE NESTS.

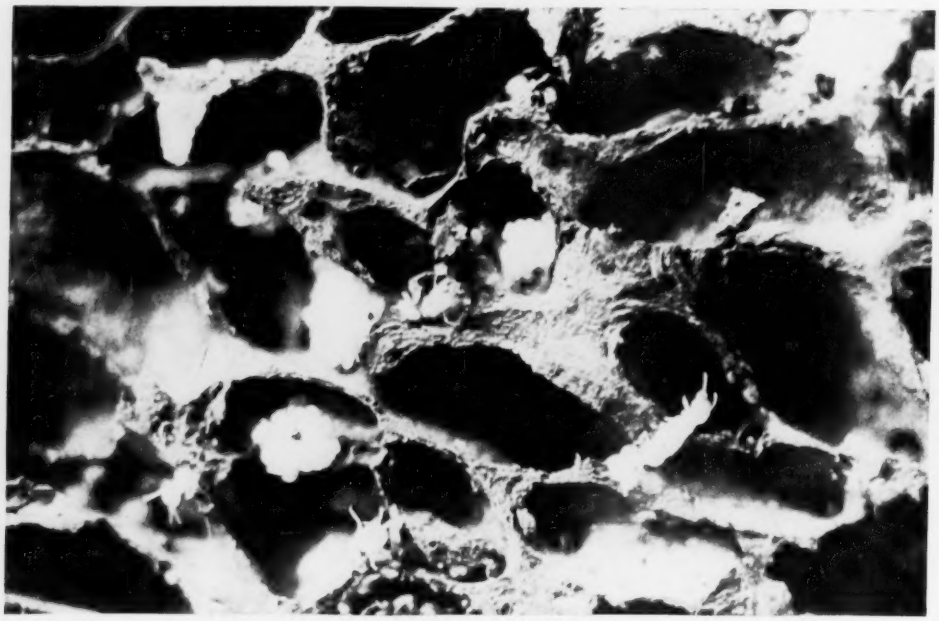
THE REPRODUCTIVE CHAMBER OF THE CARTON-BUILDING *Nasutitermes* IS LOCATED IN THE MORE OR LESS CONCENTRIC CENTER OF THE TERMITARY. THIS SECTION, TO WHICH THE MACHETE IS POINTING, IS THE THICK WALL OF THE "QUEEN'S CHAMBER."

nest by burrowing farther into its wood-nest, if the colony is built like the diffuse (*Kalotermes*) type of nest, or it constructs in ever-growing size the large solid masonry of the termitary if it belongs to the type of termite that builds concentrated nests.

The reproductive queen, meanwhile bursting with eggs at the swelling of her ovaries, no longer feeds herself; with the male "king" (who throughout his life retains more or less his original size) she is gradually imprisoned in the expanding termite realm. Some termite queens from Africa have been collected that are as long as four inches and as thick as one's finger, lording it over all the individuals of the termitary by as much as 20,000 times their volume. Such queens, thought to be long-lived (ten to forty years), are estimated to lay as many as 6,000–7,000 eggs a day or estimated 100,000,000 eggs during their productive life; thus the termite outrivals in fecundity any other terrestrial animal.

The Soldier

To defend the termitary, the termites gradually evolved a soldier caste, a curious aberration, for its defense. In the words of M. Maeterlinck, they are "a caste of nightmarish monsters which recall the most fantastic deviltries of Hieronymus Bosch, Breughel the Elder, or Jacques Callot." Blind, apterous and, in most cases, sterile, the soldier caste has but one task—to defend the colony from the attacks of ants. Physiologically it can do little else; its mandibles are greatly elongated and not made for eating. Forged into massive crushing weapons or shaped in truncated fashion to block up the entrance to the burrowings of the colony, the mandibles are



EGG CLUSTERS AND YOUNG NYMPHS IN A NEST OF *MICROCEROTERMES* OF GUATEMALA. AFTER THE EGGS ARE FRESHLY LAID BY THE REPRODUCTIVES, THEY ARE CARRIED INTO THE HUMID SECTION NEAR THE HEART OF THE TERMITARY. THE EGGS ARE MOVED SEVERAL TIMES A DAY SO AS TO KEEP THEM IN THE WARMEST AND MOST MOIST AREA OF THE NEST. THE EGG-CLUSTERS ARE IN THE CENTER AND THE FRESHLY HATCHED WHITE NYMPHS, NEAR THE SIDE.

highly functional. In other species like the *Capritermes*, the mandibles are twisted into spring-like, snapping organs, used for tremendous nipping power and, at the same time, of utility for striking against the termitary to signal an approaching danger. The very ultimate in a soldier form is the warrior of higher termites, the *Nasutitermes* (named after the fantastic nasute soldiers) which, through a directive functionalism of the ordinary cephalic gland in the soldier's retort-like head, has been so hyper-developed that these insect soldiers can project into space thin streams of a very viscose fluid which mechanically impedes ants by quickly coagulating.

All the 1,800 species of termites have soldiers save one unique group, the *Anoplotermes* (Gr., unarmed), which has no soldier caste; the workers themselves function in an imperfect defense for the colony. All other species of termites have soldiers whose method of defense, the structure of the mandibles, are modified to fit the particular type of nest structure built by each species. None of the soldier caste are able to eat for themselves: the mandibles made for fighting, or in others reduced to functionless points, are useless for carving wood. Only the obese, blind worker with its dentated mandibles, crossing scissor fashion, is able to carve wood and pass it through its intestines. The workers eat for the whole colony, by regurgitating partially digested lignin foodstuffs into the labrum of the soldiers, the king, the queen and the young of the colony. The worker alone is capable of maintaining the colony and cultivating the fungus that some Indo-Malayan and African species nurture in their nests: so the termite worker, fragile, blind, wingless, although indefatigable, controls the whole isopteron realm through its stomach. This should be a valuable pointer for the socialist.

A TERMITE "GUEST"

THE TERMITOPHILE IS AN APTEROUS PARASITIC BEETLE LIVING IN INTIMATE RELATIONSHIP WITH THE TERMITES. WHILE IT OFTEN LIVES OFF THE NEWLY HATCHED BROOD OF TERMITES, IT CEMENTS ITS FRIENDSHIP WITH ITS HOSTS BY EXUDING FROM ITS ANAL EXTREMITIES A SECRETION WHICH IS EAGERLY LAPPED UP BY THE TERMITES. THIS IS A NEW SPECIES, *Eburniola gastrovittata*, COLLECTED BY THE AUTHOR.

A PLURALITY OF QUEENS

TERMITES OF DIFFERENT SPECIES VARY IN HABIT AND BEHAVIOR. IN THIS NESTING SECTION OF A LARGE NEST OF *Amitermes*, THERE ARE NUMEROUS FERTILE QUEENS. THE SMALLER TERMITES IN ATTENDANCE AROUND THEM ARE WORKERS.

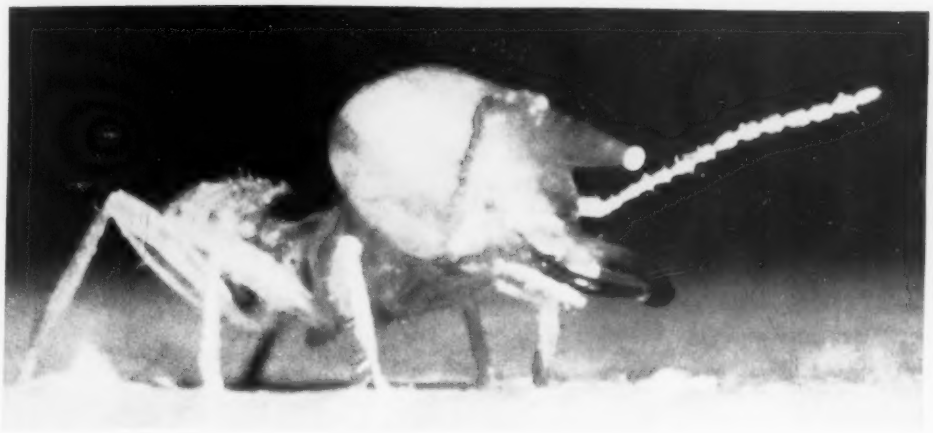
A form of sexual castration is apparent in all the social insects; but the termites have worked out a method so logical in the manner in which fertility is controlled that it borders on the fantastic. If all the termites of a colony were permitted to reproduce without restraint, the population would soon outrun the available food supply. Among termites the extraordinary fertility of the queens would be such that the termitaries would develop beyond all central original male and female reproductives. But until these supplementaries are needed they are held in check by what one eminent American termitologist believes is an "inhibiting substance" generated by the "reigning" termite queen which prevents the developement of these supplementary reproductives. Termite "queens" are well known for their exudatary secretions which are eagerly lapped up by the other members of the termitary. If the colony grows to such

J. M. Leonard

A REMARKABLE PHOTOGRAPH OF A TERMITE SOLDIER

CHEMICAL WARFARE IS NOT ALONE THE INVENTION OF MAN. IN TERMITE COLONIES, A CASTE OF NEUTERS CALLED "SOLDIERS" DEFEND THE TERMITE REALM BY MEANS OF EJECTING INTO SPACE A STICKY VISCOUS SUBSTANCE FROM THE ELONGATED *nasute* OF A CAPSULE-SHAPED HEAD. THIS IS *Armitermes perarmatus* OF ECUADOR, IN ACTUAL SIZE LESS THAN 5 MM.

control. Reproduction, then, is restricted to fertile castes, while the workers and soldiers are reduced to physiological sterility. However, there is another fertile caste that is composed of potential egg-laying females who do not swarm, for their wings are only partly developed —hence they are known as brachypertous reproductive (apertous—wing, brachy—short). These castes can be developed into fertile egg-laying reproductives by a process, which is still biologically obscure. These castes supplement the a point that the supplementary queens are unable to obtain any of this inhibiting substance, which chemically tends to suppress the development of their ovaries, or at least regulate and retard the appearance of the reproducing organs, the supplementaries increase until the realm becomes polyarchic. In the opinion of Dr. Emerson, there is evidence of a sort of social hormone in the termites "which influences the coordination of the parts of the society much as true hormones of our bodies are known

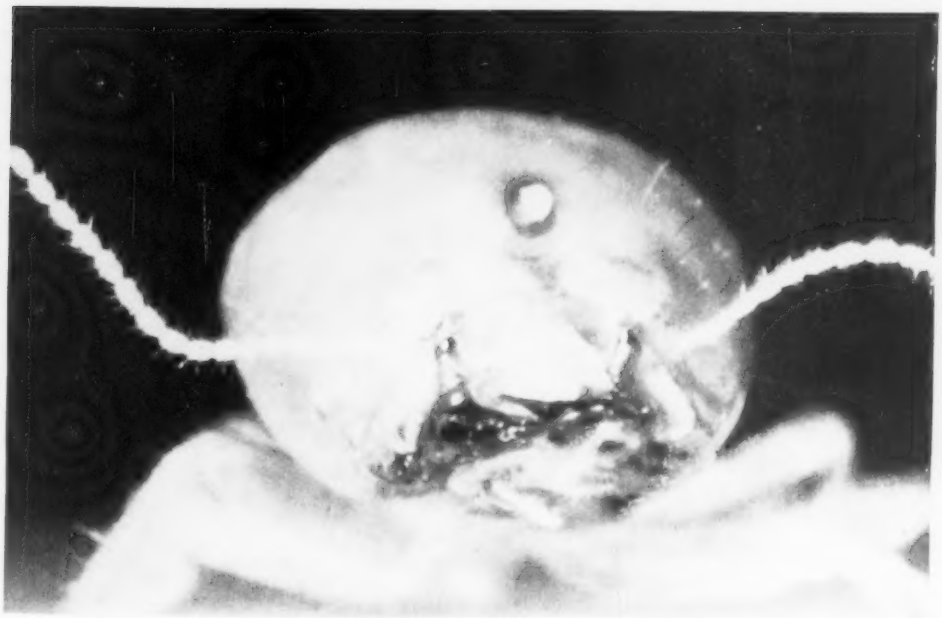


A MONSTER FROM THE INSECT WORLD—A SOLDIER *ARMITERMES*
KNOWN ONLY IN THE NEOTROPICAL REGION. THE REDDISH-BROWN AND STRONGLY CURVED MANDIBLES ARE USED WITH THE "NOSE" THAT PROJECTS FROM THE HEAD AS MEANS OF DEFENSE.

to produce a balance of functional relationships through their inhibiting or accelerating effect."[2]

What, then, operates this curious social organism, this symplasm of fragile, primitive, although preeminently social insect? If the king or queen are merely reproductives, imprisoned in their cells in the center of the darkness of the hypogeum, if the worker is sexless, eye-

[2] ALFRED E. EMERSON, *Natural History*, April, 1937.



LOOKING FACE TO FACE WITH A TERMITE SOLDIER
THE FRONTAL VIEW OF AN *Armitermes* SOLDIER AS AN ANT MIGHT SEE IT.

less and the soldier equally sterile, blind, even unable to eat for itself, what are the guiding factors of this organism? M. Maeterlinck, who wrote a very readable book—"The Life of the Ant"—which alas, contains vestiges of an unbridled (*unbridled*) mysticism, answers this question "easily"; the termite realm is operated by an "occult power," a "collective personality." Like his "spirit of the hive" in his "Life of the Bee," this "occult power" explanation is so removed from actual contact with reality that it explains nothing.

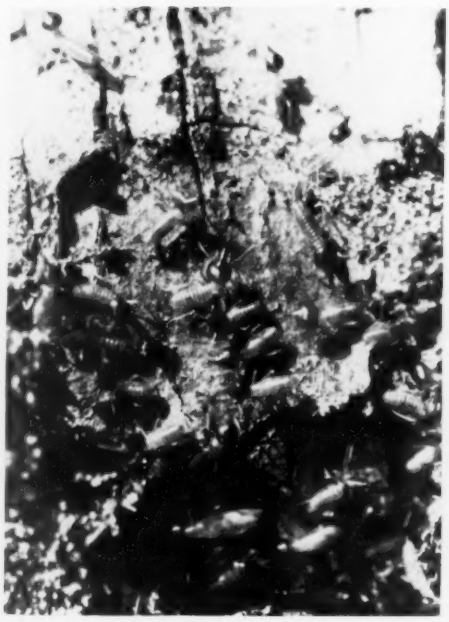
Naturalists have come to feel that they are dealing with nothing mystical in the termite realm. The insect, like most animal life, is composed of behavior cycles—it is part of life and as "*la vie est faite de vie rien ne vit qu'aux depens de la vie*," termite behavior is discernible if studied minutely enough. The habits of termites are made up of "appetitive or aversive cycles" of impulses of hunger and sex (as in man), repeated ceaselessly throughout the termite's life-span, so that the whole of these appetitive cycles become very elaborate habit-patterns, which we call, for lack of a better name, "instincts."

THE RAIN-SHEDDING DEVICES OF THIS AMAZONIC TERMITE NEST ARE THE STUDDED POINTS. OTHER SPECIES OF TERMITES USE CHEVRON-SHAPED ANGLES TO DRAIN WATER FROM THE SURFACE OF THE NEST.

THE STUFF OF TERMITE WARFARE IS THIS COAGULATED LATEX-LIKE LIQUID WHICH THE *Nasutitermes* SOLDIER SECRETES FROM ITS CEPHALIC GLANDS. THE PURPOSE OF THIS DEFENSE AGAINST THE ATTACK OF ANTS IS TO CHANGE THE NEST ODOR OF THE ATTACKERS AND TO DESTROY OR LIMIT THEIR ANTENNAL SENSE.

These "instincts" of the termites are only observed under abnormal conditions so that this may account for much of our ignorance concerning the phases of their life cycle.

If we understand that each division within the termite colony is a specialized caste which responds through its own physical limitations or attributes to a



NASUTE SOLDIERS GATHER

TO DEFEND THE REALM. A BREAK IN THE NEST BRINGS IMMEDIATE RESPONSE FROM THE SOLDIERS, WHO QUICKLY FORM ABOUT THE BREACH, THEIR HEADS POINTING OUTWARD, PREPARED FOR AN ATTACK. THE WORKERS BEGIN AT ONCE TO CARRY UP WOOD PARTICLES TO CLOSE THE BREACH.

given stimulus we may think of the entire colony as one complex socio-biological organization.

The termite organization has been successful, and it has survived for millions of years merely because of the termites' ability to temporize and to compromise with other organisms, such as the protozoa (the one-celled amoeba that is harbored in their intestines which assists in the absorption of the cellulose) and because of their ability to inhibit certain anti-social activities such as the growth of fertile supernumeraries; to suppress the extra-social activities of the aequipotential units in the interests of the whole—in short, to secure survival as a social unit through a kind of egoistic altruism. That is the triumph of the termite.

Termite Control

Control of such a complex group as the termite is not simple. Man has accentuated termite infestation by making available concentrated wooden structures, or buildings composed in part of wood over the termite's traditional habitats. By doing this, man has become an important adjunct to the termite's cellulose-cycle. Man, too, has caused the termites to spread out of their traditional habitats by the internationalization of commerce. Lumber from the United States has brought in the heartwood of Southern sugar pine a North American termite to Europe. Commerce has spread some other species through the Pacific Islands. Termites introduced to Santa Helena in 1860 destroyed more than $1,300,000 worth of property in a relatively short order. In the United States the annual damage is estimated at

A MICROSCOPIC ENGINE OF WAR

PROGRESSIVE EVOLUTION AMONG TERMITES HAS EVOLVED THE MOST FANTASTIC OF DEFENSE MECHANISMS. THE SOLDIER OF *Nasutitermes*, SO-CALLED BECAUSE OF THE LONG NASUTE OR NOSE, PROTECTS THE NEST BY EJECTING FROM THAT NOSE A STICKY VISCOUS LATEX-LIKE SUBSTANCE WHICH QUICKLY HARDENS WHEN EXPOSED TO THE AIR. IT IS GREATLY FEARED BY ANTS, FOR WHICH THIS DEFENSE HAS BEEN EVOLVED. TO GIVE SOME IDEA OF ITS SIZE, THIS TERMITE IS MOUNTED UPON THE END OF A MATCHSTICK.

$40,000,000, mostly done to outlying farm buildings where there has been figured a one per cent. damage to the $65,000,000,000 worth of farm property. The cause for this immense damage in the United States is that there are over fifty-eight species of termites found in almost every state in the Union, whereas in Europe there are found only two species of termites. As much as the British resident may grumble about the British climate, England has so far been safe from the depredations of the termite (although from the fossil records Britain had in past ages a number of termites, the island, as far as is known, is free of this destructive insect). Had England possessed a warm and equable climate, undoubtedly the termite would have taken root; for there can be no question of the fact that numerous termite colonies have been brought in from time to time in wood coming from tropical countries.

A CLOSE-UP OF TERMITE ARCHITECTURE

SHOWS AN EXPOSED SECTION OF WOOD CARVED OUT BY THE MANDIBLES OF THE WORKER OF THE *Heterotermes* AND RELINED AGAIN WITH WOOD-FRASS TO FORM A NEST FOR THE COLONY.

The United States being the prime sufferer from termite infestations, most of the steps for its control have originated here. In 1927 there was formed, in northern California, a "Termite Investigations Committee," which included not only large corporations with the practical problem of termite control, but also scientists from the University of California. Funds were subscribed by the oil and telephone companies, the lumber corporations and marine organizations, in fact from every big business that had a direct interest in the control of this insect. In the course of a number of years, far-flung investigations were launched under the chairmanship of Professor C. O. Kofoid, dean of the department of zoology of the University of California. Each of the two-score investigators of the problem was given a different phase of the investigation, each specialist carrying out his work in his own technological field. The habits of termites were thoroughly investigated, their manner of swarming, the study of all the appetitive cycles, in an attempt to uncover and interrupt the chain of events in the life cycle of the insect at some weak or accessible link. The association of fungus with termites, the spread of dry rot into galleries excavated and abandoned by termites, and another important matter, the types of wood relatively termite-resistant, were carefully

THE LESSER ANT AND TERMITE EATER, THE *TAMANDUA*

THE *Tamandua tetradactyla* HAS A LONG SNOUT LIKE A FOX AND A WORM-LIKE TONGUE, WHICH IT THRUSTS INTO TERMITES NESTS AFTER BREAKING OPEN THE CARTON WITH ITS SHARP CLAWS. THIS SPECIES OF ANT-EATER IS BOTH TERRESTRIAL AND ARBOREAL.

THE GIANT ANT-EATER OF THE AMERICAN TROPICS

A FACTOR IN THE CONTROL OF TROPICAL INSECTS IS THE ANT-BEAR, *Myrmecophaga jubata*, WHICH DESTROYS AN INCALCULABLE AMOUNT OF TERMITES. IT HAS NO TEETH, AND THE ORAL APERTURE IS JUST LARGE ENOUGH TO PERMIT THE EXTRUSION OF A ROUND VERMIFORM TONGUE.

THE SILKY ANT-EATER, WHICH LIVES WHOLLY ON TERMITES AND ANTS

MANY MAMMALS HAVE DEGENERATED PHYSICALLY TO BECOME EXCLUSIVELY INSECTIVOROUS. ONE OF THESE IS THE SILKY ANT-EATER, *Cyclopes didactylus*, WHOSE SLIT-SHAPED MOUTH IS EQUIPPED WITH A LONG MUCOUS-COVERED TONGUE FOR LAPPING UP THE INSECTS.

scrutinized. Botanists and foresters took up the phase of the growing tree, knowing that as it is not a static organism, but a dynamic one, changing with the seasonal rhythm of metabolism and growth, to ascertain its susceptibility to attack by termites. The quantities of the movements of sap and its richness in lignin in its relation to the infestation of termites were studied and subjected to experimentation. Commercial organizations experimenting with the impregnation of woods, chemicalized woods, were invited to submit samples of chemically impregnated wood to the investigation committee. In turn, these were submitted to long-range tests in the tropics as well as in the temperate zones to ascertain in each particular sample, first, its comparative immunity from termite attack and, second, to discover whether or not the chemicals with which it was impregnated would leach out under the soil.

So it went on: every termite problem tested, perfected, experimented with, until the final reports of this vast experimentation were placed in the hands of the university printer.

From the California press in 1934 came a seven-hundred page volume, "Termites and Termite Control," embodying contributions from the specialists in all the technical fields that the termite entered when it began to carve away man's buildings. It is the most complete volume on the subject; in several fields it is exhaustive and, what is more, a noteworthy monument to the necessary synthetization of objective "big business" and "subjective" science.

The book contains no one panacea. The investigators realized that they were dealing with, if not a sagacious animal, at least an insect that intuitively adjusts itself quickly to changing conditions.

A social organization before the Age

of Reptiles, the termite colony has lived through the cataclysmal changes that have come over the world and has survived when most of the other contemporary inhabitants of that period perished. It was content to live on natural plants until man placed his houses over the parts where the vegetation had grown, so it readily adapted itself to that "sapient" structure. While the most unanthropomorphic naturalist might readily admit that termites possess powers and senses of which we have only a rudimentary knowledge, and that these senses render unnecessary the multitude of auxiliary appliances indispensable to our form of civilization, he would insist that the social insects, despite the perfection of their society, differ mostly from—and are grossly inferior to—man in their not having learned the use of tools.

Man, too, would have remained in the primitive anthropoidal stage if he had not learned the use of tools by which he could add to (even if he does periodically destroy certain phases of it) a cumulative culture. Although termites should have grown wiser by the numbers of libraries they have consumed, there is little evidence of their bequeathing bank accounts to libraries or other public institutions, a seemingly important corollary in advancing the mores of society.

We are told by spectacular writers that soon we are to enter into the Age of Insects and that the termites will play a fantastic part in that insectivorous dominance. But I doubt it, if for no other reason than the actual structure of the insect. Julian Huxley recently wrote an essay on the "Uniqueness of Man"; in it he has something to say about the evolution of insects:

> The breathing mechanism has cut off insects from making great progress. The land arthropods adopted methods of air tubes or tracheae branching to microscopic size and conveying gases directly to and from the tissues instead of using dual mechanisms of lungs and bloodstream. Laws of gaseous diffusion are such that respiration by tracheae is extremely efficient for very small animals, but becomes rapidly less efficient with increase of size, until it ceases to be of use at a bulk below that of a house mouse. It is for this reason that no insect has become moderately large by vertebrate standards or moderately intelligent.

And this limitation of insects applies equally well to the termite, or white ant.

SAVING THE PAST FOR THE FUTURE

HUMAN lives are not the only casualties in war. Cherished wherever civilization has existed are the irreplaceable relics of the past—buildings, monuments, books and manuscripts. Nowhere is that store richer or in greater danger than in England. Already destruction has been extensive. Many noble buildings are rubble and many unique records have been destroyed. At the University of London, to take one instance, the Egyptology collection was badly damaged by water, the Mocatta Library and collection of Anglo-Judaica were shattered by incendiary bombs and over 100,000 books were consumed in the fire. Other libraries, too, have been destroyed, involving the loss of thousands of books. There are no duplicates of much of this material; it can never be replaced. Fortunately, however, most of the valuable records of England are still unharmed. In the hope of preserving for the future the substance of this universal heritage, and of making it available to scholars everywhere, the Foundation, in 1941, appropriated funds for two emergency projects for copying and recording important historical, literary and architectural treasures.—*Raymond B. Fosdick in "The Rockefeller Foundation Review for 1941."*

SOIL EROSION AS AN ECOLOGICAL PROCESS

By Dr. EDWARD H. GRAHAM

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WITH respect to their influence upon habitat there is a significant difference between normal or geological erosion and man-made or accelerated soil removal. Erosion induced by man may cause unusually rapid and profound changes in environment; furthermore, it is now so wide-spread throughout the world that it critically reflects itself in the social and economic welfare of nations. Although much has been written within the past decade about the influence of vegetation upon run-off and erosion, scant literature has appeared relating to the opposite effect; that is, the influence of erosion upon plants and animals. It is the purpose of this paper to note something of the influence and importance of man-induced soil erosion as a process affecting the habitat. Attention will be directed to differences between undisturbed and eroded soils, and to ways in which accelerated erosion affects living things.

Although it is a significant and wide-spread phenomenon, man-induced soil erosion has been much neglected by ecologists. Although grazing, lumbering and fire due to the activities of man have long been recognized as environmental influences, practically no text-books on ecology have considered accelerated soil erosion as an important ecological process. This disregard is also well illustrated by the fact that until a few years ago many extensive agricultural field investigations were conducted with careful consideration of climatic factors, application of fertilizer and crop yields, but with no consideration of erosion, which in many instances was removing soil from the land on which the experiments were being conducted at a rate sufficient to invalidate the results of the investigations.

Recent theories of soil genesis acknowledge five influences in the production of natural soils; namely, climate, native vegetation, underlying rocks, relief or slope and age. That soil is the result of the dependent interaction of these several factors replaces the older idea that soil is simply decomposed rock —a result of destructive weathering—or that it results entirely from vegetation. Such modern concept greatly influences one's thinking with regard to accelerated erosion, for if soil were only decomposed rock or consisted simply of vegetative remains, soil removal would be a less serious matter than it is. A given soil type, therefore, is the result of continued interaction of several processes, including the physical disintegration and chemical decomposition of mineral constituents and the recombination of some of the resulting substances. Such substances, together with organic materials composed of plant and animal residues, are being constantly redistributed as a consequence of water movement, leaching and the activities of the soil microflora, microfauna and, to a lesser extent, larger animals such as earthworms and burrowing rodents. These physical, chemical and biological processes normally maintain a soil profile of definite depth and composition, usually of three well-defined yet genetically related horizontal layers, the A, B and C horizons (Fig. 1). The A horizon is popularly called topsoil, the B, subsoil. Together they constitute the solum, or true soil. Below them is the C horizon consisting of parent material that is weathered but still unchanged by

other soil-building processes. Underlying the C horizon is the unweathered and completely unchanged parent material.

In very broad terms, it may be said that normal erosion, a process as old as geological history, is in most regions of the world an imperceptibly slow, although persistent action. It is usually so gradual that as upper portions of the soil profile are removed by wind or water, soil-building processes replace them and develop the lower portions to compensate for the removal. The result is the gradual downward progress of the entire profile and, geologically, eventual leveling of the landscape or peneplanation. The first effect of man-induced erosion is the removal of portions of the A horizon at a rate faster than formative processes can replace them—an effect evidenced by sheet erosion and the formation of rills (Fig. 2). If the process continues, sheet erosion may be followed by the removal of portions of the B horizon and the development of gullies. Gullies may erode into the C horizon and are known in many instances to have cut below it to remove portions of the parent material also (Fig. 3). The loss of soil by such process is, on land under human occupations, serious and costly and not easily amended by the application of fertilizer or improved soil-management practices.

Physical and Chemical Conditions

Soil science has demonstrated great differences in the physical condition of various soils attributable to texture, content of organic matter, character of colloids, porosity and content of water and gases. Even a superficial knowledge of the nature of soil profiles, however, indicates that there may be less variation in the physical condition of the A horizons of different soil types than there is between A and B horizons of the same soil profile.

In general, at least during the growing season, soil temperature decreases with depth of soil. Likewise lower horizons of an undisturbed soil frequently have lower water and air capacities than the surface layer. A definite relationship exists between available water and the physical structure of the soil, and it is known that infiltration rates vary greatly for different soil types and for different horizons of the same soil. When the topsoil with its porous structure is removed by erosion, the temperature, water-holding capacity and other physical features of the exposed substratum are, therefore, markedly different from those of the undisturbed soil.

Experiments have shown that muddy suspensions percolate through soil col-

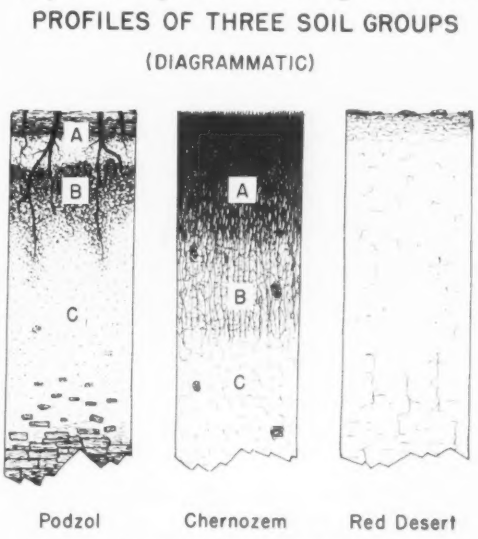

FIG. 1. PROFILES OF SOIL GROUPS

PODZOL, CHERNOZEM AND RED DESERT. THESE PROFILES CHARACTERIZE SOILS DEVELOPED RESPECTIVELY UNDER FOREST, GRASSLAND AND DESERT CONDITIONS. NOTE THAT THE A, B AND C HORIZONS OF THE PODZOL DIFFER IN THICKNESS AND COMPOSITION FROM COMPARABLE HORIZONS IN THE CHERNOZEM, AND THAT THE RED DESERT SOIL IS WITHOUT DISTINCT HORIZONS. THERE IS FREQUENTLY GREATER PHYSICO-CHEMICAL AND BIOLOGICAL DIFFERENCE BETWEEN THE A HORIZON OF A VIRGIN SOIL AND ITS RELATED LOWER HORIZONS THAN THERE IS BETWEEN THE A HORIZONS OF DIFFERENT SOIL TYPES DEVELOPED UNDER TOTALLY DIFFERENT CLIMATES.

umns at about one tenth the rate of clear water. Concerning this relationship Bennett[1] has said that a natural cover of vegetation "prevents the formation of soil suspensions by rainwater at the surface; the water remains clear, and the rate of intake is maintained at the natural capacity of the soil profile. But bare soil surfaces produce muddy suspensions under the impact of rain, and such suspensions . . . tend to seal off the surface, thereby reducing the rate of intake of water into the soil." Here then is one reason why the destructive aspects of accelerated soil erosion are cumulative, for, within limits, the more silt suspended the higher the run-off, and the higher the run-off the greater the power of water to erode the soil.

Although it is recognized that organic matter can not be expressed exactly by the carbon-nitrogen ratio, a figure denoting the proportion of carbon to nitrogen in the soil is nevertheless a useful indicator of soil organic matter. Even for such divergent soil groups as Chernozems, Podzols and Laterites (Fig. 1), there is known to be a steady decrease of the carbon-nitrogen ratio with depth. The ratio in the A horizons is higher than in related B horizons and for each soil group the ratio in the B horizon usually averages higher than in the underlying C horizon. A recent study of several important agricultural soils from various parts of the United States, for example, showed that organic matter averaged a drop from 4.3 per cent. in topsoils of virgin or slightly eroded condition to 1.0 per cent. in erosion-exposed subsoils of corresponding types nearby. As far as organic matter is concerned

[1] H. H. Bennett, "Soil Conservation," p. 206, New York and London, 993 pp., 1939.

FIG. 2. SHEET EROSION IN A CALIFORNIA GRAIN FIELD

SHEET OR RILL EROSION FREQUENTLY CHARACTERIZES THE REMOVAL OF THE A HORIZON OF THE SOIL PROFILE. INCIPIENT GULLIES INDICATE A TRANSITION TO A MORE SEVERELY ERODED CONDITION.

FIG. 3. MISSOURI GULLIES THAT CUT THROUGH THE SOIL PROFILE DEEP INTO THE PARENT MATERIAL. FOLLOWING THE REMOVAL OF THE *A* HORIZON, EROSION INTO LOWER HORIZONS INCREASES, EVEN TO THE EXTENT OF CAUSING A COMPLETE CHANGE OF LANDSCAPE.

the different horizons of the same soil may be considered as distinct as the surface layers of different soils developed under different climatic conditions.

It is likewise recognized that amounts of essential elements vary with depth of soil. As a general rule, the content of nitrogen in soils is greatest in the plow level and decreases with depth; this is like the change with respect to organic matter. That phosphorus near the surface may be most available to plants is also indicated by experiments which show that in the surface of many soils approximately one third of the phosphorus present is in organic combinations, while in subsoil only about one fifth of the total phosphorus is in such available form. The potash (K_2O) content of soils may not display such a general correlation with soil depth, but the potassium cycle is a relatively simple one with no great quantities accumulating, as with nitrogen in proteins or phosphorus in bones, and because potassium remains essentially soluble its waste by soil erosion can be particularly significant. The hydrogen-ion concentration also varies with soil depth.

Although it is recognized that deficiency of a chemical element may limit the growth of a plant species, too much importance should not be attached to single elements or isolated characteristics of the soil as habitat factors. Together, however, physical and chemical properties of soils combine to establish the soil as a habitat entity, and inorganic constituents of the soil can be sufficiently changed by accelerated erosion to produce a soil and habitat condition different from that existing on the same site before such erosion occurred.

Soil Biota

In addition to physical and chemical changes in the soil induced by erosion, there are comparable changes in the soil

biota. Normal habitats for shrews, moles, burrowing rodents and other vertebrates are materially altered by man-induced soil removal, but it is undoubtedly upon invertebrates and the microbiota of the soil that erosion has the greatest effect. It has long been known that the numbers of bacteria in humid regions decrease with depth of soil. There is a corresponding correlation between soil actinomyces and soil depth and it has also been demonstrated that soil protozoans may be practically confined to the uppermost few inches of soil.

Experiments have disclosed some interesting relationships between the normal microflora of a given soil and the number of microorganisms to be found in the eroded material from that soil. Expressed as numbers in each gram of dry solids, the average total number of microorganisms in run-off is known in some instances to exceed that in the original soil by about 200 times. The organisms are either adsorbed by the soil particles or suspended in the transported materials, and their removal demonstrates the great reduction of soil microorganisms which accompanies the loss of soil particles by erosion.

Jacot[2] has emphasized the great importance of microarthropods in maintaining normal soil structure and states that the depth to which such a fauna penetrates is probably equivalent to the depth of root penetration. His investigations of various soils in North Carolina show reduced populations of these small arthropods with increase in soil depth. For example, 2,800 saprophytic mites per square foot were counted in the top 3 inches of soil, while 10 to 13 inches below the surface only 28 of these organisms occurred. Likewise the number of saprophytic insects and myriapods dwindled from 500 per square foot 1 to 3 inches below the surface to 22 at a depth of 10 to 13 inches. Such studies also demonstrate that soil erosion eliminates the porous channeled layer in which microarthropods are most abundant, and that repopulation of abandoned agricultural land by these organisms is very slow. The soil microbiota is inextricably associated with the maintenance of normal soil structure, and because it is most extensive in the A horizon and less well represented at greater depths, the removal of the upper parts of the soil profile results in the loss of most of these very valuable organisms.

Crop Yields

The most convenient biological index of the effect of accelerated erosion is the growth of higher plants. Plant growth indicates this effect by crop yields produced respectively on A and B horizons of the same soil type, and by the vegetation naturally occupying eroded areas. Recent experiments by the Soil Conservation Service reveal that on 10 representative types of farm land under comparable conditions of slope, rainfall and cultural treatment, the per acre yield of several agricultural crops on subsoils was materially less than the yield produced on topsoils of the same soil types. Latham[3] has recently compared the productivity of the A horizon of Cecil sandy loam with that of the B and C horizons exposed by erosion, as determined by the yield of seed cotton produced in experimental plots. Under the conditions of the experiment the A horizon proved more than three times as productive as the B and eleven times as productive as the C horizon.

Furthermore, the rate of erosion usually is not retarded when the topsoil is removed, but may then increase to cut downward into the parent material which in almost all cases is less productive than any of the layers above it.

[2] Arthur P. Jacot, *Ecology*, 17: 359–379, 1936.

[3] Earle E. Latham, *Jour. Am. Soc. Agron.*, 32: 950–953, 1940.

Even with heavy application of fertilizer it is generally impossible to bring the yield from subsoil up to that from the related surface soil, so great is the difference in their composition. This difference is important, for in spite of higher quality seed, more productive varieties of crop plants, better fertilizers and improved cultural practices, the average per acre yield of cotton for the United States has declined materially, corn has not quite held its own, and even the yield of wheat has increased but slightly.

Of course, the reasons for such decline can not be easily assigned. Increased use of farm machinery during the past several decades has emphasized greater production at the expense of acreage yield, and the extension of agriculture into regions less suitable to major crops has also tended to reduce production per acre. There is considerable evidence to indicate, however, that accelerated soil erosion is a factor that has contributed importantly to the limitation of crop yields on agricultural lands.

Native Vegetation

But the ecologist need not look to agricultural statistics alone for the effects of humanly provoked erosion. In studies of the establishment and succession of vegetation on different soil horizons, Sinclair and Sampson[4] experimentally demonstrated that on certain California soils the amount of plant material produced and the growth rate of both annual and perennial wild plants were appreciably greater in soil horizon A than in lower horizons. For example, in Holland soil, the growth of *Stipa pulchra*, a climax species, at maturity in horizon B was 23.88 per cent., and in horizon C, 20.63 per cent., of the growth in horizon A. Flowers bloomed earlier on plants growing in the A horizon, while on B and C horizons perennial

[4] J. D. Sinclair and A. W. Sampson, *Hilgardia*, 5: 155–174, 1931.

FIG. 4. SEVERELY ERODED AREA IN THE APPALACHIAN PIEDMONT OF NORTH CAROLINA. SHORTLEAF PINE (*Pinus echinata*) IS INVADING THE ERODED SITE WITHOUT THE CONDITIONING OF HERBACEOUS PLANTS THAT USUALLY PRECEDES THE WOODY VEGETATION.

H. L. Shantz

FIG. 5. DESERT SHRUB IN THE SOUTHWESTERN UNITED STATES

WHERE CREOSOTE BUSH (*Larrea tridentata*), A COMPONENT OF THE NATURAL VEGETATION, MAY IMMEDIATELY REPOPULATE AN AREA AFTER IT HAS BEEN DISTURBED.

FIG. 6. SILT DEPOSIT ALONG A STREAM IN TENNESSEE

DEPOSITION OF EROSION SEDIMENT ALTERS STREAMS AND PONDS AS HABITATS FOR AQUATIC LIFE.

species produced practically no seed. The growth of non-climax weed species, however, showed comparatively slight differences when grown on the various soil horizons. In these experiments the water requirements of plants were shown in all cases to be higher in horizon C and in most cases in horizon B, than in the A horizon. This fact emphasizes the deficiencies that eroded soils may create in the plant habitat, for, as already pointed out, the rate of percolation of muddy water is only a fraction of that of clear water. Thus in eroded soils water requirements of plants are particularly high where available water is comparatively low.

Range type and degree of erosion on the Boise River watershed have been related by Renner,[5] who pointed out that the range with the most gullies was populated with a weed community representing an early successional stage. Studies also show correlations between accelerated soil erosion and vegetation in which both the forage density and vegetation density vary inversely with the degree of erosion, while the deterioration in plant cover increases as erosion becomes more severe. Others have touched upon this relationship, including Bennett,[6] who has described in general terms some of the types of vegetation inhabiting eroded areas throughout the United States.

Succession

Recent studies have demonstrated a definite relationship between the stages of plant succession and soil erosion, and variations in biotic communities under different types of land use have been described. Related changes of physiography and of animal populations, including various groups of insects, birds and mammals, have also been correlated with intensity of accelerated erosion.[7] More studies of this type are needed, for they may aid in revising some ecological concepts. Perhaps more important, they can be of value in the development of sound land use practices which in many instances are of necessity based upon insufficient and inadequate data.

One can not observe serious erosion, especially as it exists in the Appalachian Piedmont, without wondering if we do not need some adjustment of our theories about plant succession. Many bare areas caused by soil erosion remain free of expected pioneer species for many years —possibly as long as the existing rate of accelerated erosion persists. Frequently, when invasion does occur on eroded soils in the Piedmont, it does not start with herbaceous stages and proceed from annuals to perennials, to broomsedge (*Andropogon virginicus*), to pine, as the theory of secondary succession academically demands. Instead, loblolly or shortleaf pines may invade a highly eroded cultivated field soon after it is abandoned. Where seeds are available, the immediate development of a stand of pines seems to exclude or perhaps, telescope, all the earlier successional stages. On severely eroded soils the invasion of pines apparently does not require conditioning by weeds and other herbaceous plants that usually precedes the establishment of pines under other circumstances (Fig. 4). This direct progression from bare area to pine forest is one scarcely consistent with a rigid interpretation of most concepts of plant succession.

Concepts of succession have, for the most part, been developed by ecologists dealing with vegetation of humid regions. It now appears that such concepts must be modified, particularly with respect to the changes of vegeta-

[5] F. G. Renner, *U. S. Dept. Agr. Tech. Bull.*, 528, 32 pp., 1936.

[6] H. H. Bennett, Sci. Monthly, 35: 385–415, 1932.

[7] Charles Clinton Smith, *Ecol. Monographs*, 10: 421–484, 1940.

tion in arid areas. In parts of Mexico and the arid southwestern United States desert shrubs are dominant components of the original, undisturbed vegetation (Fig. 5). There is reason to believe that when this natural, or climax, vegetation is disturbed, these same shrubs and associated species immediately repopulate the area, and that there occur none of the stages of vegetation usually believed to precede the reestablishment of a climax type. It is of interest to note that in this region soil groups such as the Red Desert soils of the Mohave and other American deserts are wholly different from either forest or true grassland soils, for they are without distinct A, B and C horizons (Fig. 1). Furthermore, there may be considerable significance in the fact that the invasion behavior of pines in the Appalachian Piedmont is comparable in principle to that of the direct reestablishment of climax shrubs in desert areas. The way in which Piedmont pines populate old fields may indicate a reaction to a desert-like soil profile developed on severely eroded sites. It is possible, therefore, that accelerated erosion may so alter soil conditions, even under a prevailingly humid climate, as to create, at least for a time, what amounts to a sub-humid environment. Thus, so far as a habitat factor is concerned, highly eroded phases of soils originally developed under humid climates may be considered somewhat analogous to uneroded soils developed under desert conditions.

Aquatic Habitats

The effect of erosion upon the environment is not limited to land habitats. Its influence upon aquatic habitats may be very great, for the waters of ponds, lakes and streams have been seriously modified by siltation, and sedimentation studies stress the rapidity with which reservoirs are being filled with silt and erosional debris (Fig. 6). It is well known that when erosion fills pools with sediment or, by removing vegetation along the banks, permits the water temperature to rise, it can convert a stream once ideally adapted to trout into an environment totally unfit for such species of fish.

Much has been written about stream pollution by industrial wastes, but not much inquiry has been directed toward the damage caused by suspended soil which, however, is even more common and very probably more important as an influence upon aquatic organisms. Studies of erosion silt as a factor in aquatic environments indicate that it is a highly significant influence. Ellis[8] states that

> erosion silt and other suspensoids (disregarding any specific toxic action of suspensoid wastes) affect fisheries directly by covering the bottom of the stream with a blanket of material which kills out the bottom fauna, greatly reduces the available food, and covers nests and spawning grounds; . . . the mechanical and abrasive action of the silt itself . . . may clog and otherwise injure the gills and respiratory structures of various aquatic forms, including many fishes and mollusks. . . . Indirectly, but none the less effectively, erosion silt affects fisheries by screening out the light, by "laking down" organic wastes, and thus increasing the oxygen demand at the bottom of the stream, and by retaining many forms of industrial effluents, as oils, chemical wastes, and pulps in beds on the floor of the stream, with disastrous results to the bottom fauna.

A factor so distinctly affecting aquatic habitats must determine the existence not only of specific organisms but of aquatic plant and animal associations and their successional relationships as well. Two main successional trends of aquatic plant associations have been distinguished in English lakes, depending upon the presence or absence of silting by inorganic material. Studies of community relationships in aquatic environments as related to degree of siltation in the United States, however, have been almost neglected. Nevertheless, the evi-

[8] M. M. Ellis, *U. S. Dept. Commerce, Bull. Bur. Fisheries*, 48: 365–437, 1937.

dence at hand suggests that man-induced soil erosion may critically influence aquatic environments just as it does terrestrial habitats.

Conclusion

In summary, it may be said that accelerated soil erosion is considered an important ecological process because it produces marked changes in both the inorganic and biologic components of the environment due largely to removal of portions of the soil profile. Through such erosion, water infiltration is lessened, organic matter is reduced, and the chemical composition of the soil is materially altered as shown by depletion of nitrogen, phosphorus and available potash. Biologic changes are shown by a greatly reduced soil biota, especially bacteria, actinomyces, protozoa and microarthropods, which are normally most numerous in the uppermost layers of the soil. Higher plants indicate even more conspicuously the effects of man-induced erosion, as shown by experiments in which crop yields from undisturbed soils prove materially higher than yields from eroded phases of the same soil types; wild plant growth shows a similar correlation. Successional stages of native vegetation may in some instances be related directly to degree of erosion and it is suggested that further study of the invasion of eroded areas might result in revision of some ecological concepts. The effect of erosion is likewise evident in lakes and streams where silt alters aquatic populations and their successional behavior. The inorganic and biologic changes resulting from accelerated erosion and the extent of eroded land combine to make highly important the relation of soil erosion to habitat.

It is difficult to assign environmental equivalents to soil profiles or horizons, but it seems that there may be as much difference between the A horizon of a virgin soil and its related lower horizons exposed by erosion as there is between the A horizons of different soil types developed under totally different climates. Accelerated soil erosion, therefore, may minimize the effects of other environmental elements, such as physiography, precipitation, temperature and length of growing season. Inasmuch as the ecological importance of man-induced soil erosion may be as great as that of climatic influences, it would be of value to the ecologist to examine erosion more closely with respect to its effect upon plant and animal populations. The results of such investigations would be of considerable academic interest and would contribute to knowledge of ecological principles applicable to the revegetation of eroded areas and to the management of crops, pastures, woodlands and wildlife wherever such management is undertaken as part of a program for the conservation of soil and soil resources.

STEPHEN HALES—PIONEER PLANT PHYSIOLOGIST

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DURING the seventeenth and eighteenth centuries, when the followers of Francis Bacon were supplementing the deductive logic of the Greeks with experimentation and inductive reasoning and thereby giving birth to modern science, it was not uncommon for men who were scientists by avocation to make important scientific contributions. Although we may have been surprised to learn that Christopher Wren (1632–1723) was not only one of the greatest of architects, but also made valuable contributions to mathematics and science,[1] we all know that Benjamin Franklin (1706–1790) added to our knowledge of electricity, that Joseph Priestley (1733–1804), who discovered oxygen, was a nonconformist minister, and that Gilbert White (1720–1793) was curate of Selborne when he wrote its natural history.

Not so generally known is the fact that another English clergyman by the name of Stephen Hales was virtually the founder of the science of plant physiology, contributed much to the field of animal physiology, and was in addition something of a chemist and inventor. Stephen Hales has not been forgotten: almost every history of botany or biology at least mentions him; he has been the subject of an excellent book-length biography,[2] and the American Society of Plant Physiologists has named a prize award in his honor. However, among scientists in general and the educated public as a whole he is not well enough known. To fully appreciate the quality and importance of his work we must refresh our minds on the state of science about the time of his birth in 1677 at Bekesbourne, Kent.

Physics was becoming an exact science, due primarily to the work of Galileo, who not only studied the motion of falling bodies, stated the laws of dynamics, and helped create the science of astronomy, but is also often regarded as the founder of the experimental method. Newton published his famous "Principia" in 1687 when Hales was ten, and he dominated English science at the time Hales was receiving his education.

Chemistry had developed little beyond the flounderings of the alchemists. One of the few contributions of permanent value to the science made during Hales's time or before was Boyle's work on the gas laws (1660) and his discovery that air is necessary for life and combustion. Although Hales lived during the days of the phlogiston theory, it is interesting to note that he did not accept it, but belonged to Boyle's chemical school. To understand how little chemistry had developed by Hales's time, it is necessary only to mention that not a single chemical element had been discovered, and chemical equations were of course unknown. The true founders of modern chemistry—Black, Cavendish, Priestley, Scheele, Lavoisier—were all born at about the time of Hales's zenith, and he lived to see only Black's discovery of carbon dioxide. At Hales's time the old

[1] Dorothy Stimson, "Christopher Wren, F.R.S.," SCIENTIFIC MONTHLY, 53: 360–367, October, 1941.

[2] A. E. Clark-Kennedy, "Stephen Hales, An Eighteenth Century Biography," Cambridge University Press, 1929. The quotations from Stephen Hales and his contemporaries given here are taken from this volume.

Greek idea that all was earth, air, fire or water had been modified only to state that "earth" consisted of various mixtures of salt, mercury and sulfur.

Most of the biological concepts of the time were based on the teachings of Aristotle and the other Greek philosophers, although human anatomy had made great progress through the work of Vesalius and others. In 1616 modern human and animal physiology was set on its way by the discovery of the circulation of blood by William Harvey. Botany had advanced but little beyond Theophrastus, until the appearance of Hales's immediate predecessors: Grew, Malpighi, and Ray. Malpighi and Grew simultaneously laid a firm foundation for plant anatomy in 1671, and Ray's "Historia plantarum generalis," published in 1686, was an important milestone in taxonomy. Linnaeus was a contemporary of Hales, though he published his works a decade or more after Hales's "Vegetable Staticks" appeared.

The concepts of plant physiology as late as the seventeenth century were still based on the ancient speculations of Aristotle: that food for plants was prepared and elaborated in the earth for them, different food being prepared for each species, and that actual nutrition was controlled by a soul, probably located in the pith. Jung and Van Helmont objected to some of Aristotle's theories, but, as Sachs expresses it, "their objections remained sterile and unproductive." Ray dabbled with physiological experiments, but his methods were crude, his apparatus inadequate, and he contributed nothing of importance. While Grew and Malpighi were laying the foundations of anatomy they had the solution of physiological problems constantly in mind. However, they based their conclusions on vague theorizing rather than on experimentation, and it is hardly surprising that most of their concepts were extremely fanciful. Following Harvey's demonstration of the circulation of blood in 1616 many attempts were made to demonstrate it in plants, and it was generally assumed that circulation existed in plants, until the theory was finally disproved by Hales. Sachs summarizes the early history of plant physiology as follows:

"If we compare what was known before Malpighi's time with the contents of Hales's book ("Vegetable Staticks"), we shall be astonished at the rapid advance made in less than sixty years, while scarcely anything had been contributed to the subject in the period between Aristotle and Malpighi."[3] We may add that practically all the advance may be attributed to Hales himself.

Stephen Hales's family was one of the oldest and most distinguished in Kent. When Stephen was only a boy his father died, and Stephen was brought up by his grandfather, Sir Robert Hales. In 1696 he entered Corpus Christi College, Cambridge, from which he received his A.B. in 1699. He continued his studies and secured his M.A. degree in 1703. The same year he was elected a fellow of the college. Up to this time his work had been largely in the field of theology, although it seems that he had developed quite an interest in physical science, probably due to the influence of Sir Isaac Newton, "the shining light of Trinity."

However, he did not develop a serious interest in science until the early years of his fellowship. While the stimulation of his interest in physical science may be attributed to Newton, his interest in biology must be attributed to William Stukeley, several years his junior and an undergraduate at the time Hales was a fellow. They struck a close friendship, as indicated by the following account by their contemporary, Peter Collinson:

> They rambled over Gogmagog Hills and the bogs of Cherry-Hunt-Moor to gather simples

[3] Julius von Sachs, "History of Botany," Oxford, 1906.

with Ray's "Catalogus Plantarum circa Canterbrigiam nascentium" in their pockets, to which Stukeley, who was always a ready draughtsman, had added a map of the country, the better to direct them in their peregrinations; in some of these expeditions they collected fossils from the gravel and chalk pits; and in others they hunted butterflies, having contrived an instrument for taking them. Hales also in conjunction with his friend Stukeley applied himself to the study of anatomy, frequently dissecting frogs, and other animals, in their herbalizing walks. They proceeded also to the dissection of dogs, and Hales contrived a method of obtaining a preparation of the lungs in lead, of which Dr. Stukeley now has several specimens. They applied themselves also to chymistry and repeated many of Mr. Boyle's experiments, making flowers of benzoin, pulvis fulminanus, elixir proprietatis, and various preparations, some of use and others of curiosity: but besides what they did between them, they attended the chymical lectures that were then read by the public Professor Signoir Vigani in Queens College Cloysters, and went also to see the chymical operations which he performed in a room at Trinity College, which had been the laboratory of Sir Isaac Newton, and in which, unfortunately for the world, Sir Isaac Newton's manuscript concerning chymical principles was accidentally burned.[4]

In 1708 Hales became perpetual curate of Teddington, an attractive country village of less than five hundred population on the north bank of the Thames, fifteen miles up from London. However, he did not vacate his fellowship at Cambridge until 1718, when he also became rector of Porlock. In the meantime he had taken his B.D. degree at Cambridge and had kept in close contact with the university. He held his position at Porlock only four years, resigning to become rector of the more accessible village of Farringdon, a position which he held, along with his curateship at Teddington, until the time of his death. At that time it was customary for the better educated ministers to have several parishes and to employ less well-educated curates to take care of the smaller ones. Hales maintained his residence at Teddington, visiting Farringdon for only a month or two each summer.

[4] Peter Collinson, *Gentleman's Magazine*, 34: 273, 1764.

Shortly after Hales went to Teddington, he began his first important scientific research by experimenting on blood circulation in dogs and horses. He started out to find whether there was any truth in the current theory that the pressure of the blood in the muscles was great enough to account for muscular action. He finally disproved this theory, but in the meantime he made many other important discoveries concerning circulation. Some of his experimental methods were dramatic. He would strap down his dogs or horses, and without anesthesia (which was then yet undiscovered), he would insert a glass tube as much as thirteen feet long in various large arteries and veins and then measure the height to which the blood was forced. Garbled accounts of his experiments got around the neighborhood and there was a certain amount of objection to his work. His neighbor and good friend, Alexander Pope, had this to say:

> I shall be very glad to see Dr. Hales and always love to see him, he is so worthy and good a man. Yes, he is a very good man, only I'm sorry his hands are so much imbued in blood. . . . Indeed he commits most of these banalities with the thought of being of use to man. But how do we know that we have a right to kill creatures that we are so little above us as dogs, for our curiosity.

Hales's experiments also figured in a poetic account of a trip up the Thames, entitled "The Boat," and written by a Reverend Thomas Twining:

> Green Teddington's serene retreat
> For philosophic studies meet,
> Where the good pastor Stephen Hales
> Weighed moisture in a pair of scales,
> To living death put mares and dogs,
> And stripped the skins from living frogs.
> Nature he loved, her works intent
> To search or sometimes to torment.

A mere listing of his contributions will make us realize that whatever sufferings his experimental animals endured were not in vain. He found out that the pulse rate was greater in small animals than large ones, that blood pressure was

greater in large animals than small ones, that there was less resistance and pressure in the pulmonary than the systemic circulation and that certain saline solutions would prevent clotting. He made accurate measurements of blood pressure under various conditions, and determined the capacity of the heart, the diameter of blood vessels and the rate of flow of blood in the capillaries of the frog. He measured the pressures necessary to burst various arteries and veins. He was not satisfied with the current concept that the heat of the body was due to the friction of the blood in the capillaries, and had chemistry been as advanced as physics at the time he might have discovered the true cause. He demonstrated spinal reflexes in frogs long before the nature of nerve action was understood, and discovered that bone growth is at the symphyses, a contribution usually falsely attributed to John Hunter. He speculated that the animal spirits, as nerve impulses were then called, might be due to electrical charges. He had a remarkably clear insight into the nature of secretion. Later in life he did some important work in animal respiration, even conducting experiments on himself. Hales was a competent animal physiologist, and even if he had done no work at all in botany his name would still figure in the history of science. The writer in the "Dictionary of National Biography" claims that, "In first opening the way to a correct appreciation of blood pressure, Hales's work may rank second in importance to Harvey's in founding the modern science of physiology."

His work on circulation was not published until 1732, when it appeared in the form of a book entitled "Haemostaticks." Some twenty years had elapsed since he had done most of his research in this field. In the meantime he had become interested in plant physiology. In 1718 he was elected a fellow of the Royal Society, on the nomination of his old friend William Stukeley, and on March 15 of the same year he read before the society a paper entitled "The effect of ye sun's warmth in raising ye sap in trees." His "Vegetable Staticks," the classic which includes practically all his work on plant physiology, was published in 1727 under the Imprimatur of Sir Isaac Newton, who was serving his last year as president of the society. The importance of the volume was immediately recognized, and probably contributed largely to his election as a member of the council of the society the same year. "Vegetable Staticks" was translated into French by Buffon in 1735, into German by Christian Wolff in 1748, into Dutch in 1750 and into Italian in 1756. Both his "Vegetable Staticks" and "Haemostaticks" were gaining Stephen Hales international renown, and in 1733 they were combined in a single volume entitled "Statickal Essays." The same year he was awarded an honorary D.D. degree by Oxford.

Stephen Hales's work in plant physiology was along four principal lines: water relations, growth, nutrition and reproduction. By far the most extensive and valuable of those were his studies of water relations, *i.e.*, transpiration, conduction, root pressure and absorption.

He employed three methods of measuring transpiration: weighing, a potometer and a glass balloon for collecting the water transpired. The first two methods are still in use, and the latter has been discarded only in relatively recent years. He determined the rate of transpiration per unit of leaf area for sunflowers, cabbage, grapes, apple trees, lemon trees and a number of other plants with a surprising degree of accuracy. He discovered the daily periodicity of transpiration, and noted that "with scanty watering the perspiration much abated." He showed that evergreens transpire less

than some other plants. He first pointed out the correct explanation for the removal of some leaves after transplanting, a common custom even in those days.

His research on root pressure was suggested to him by his work on blood pressure and an accidental observation. Here are his own words from his "Vegetable Staticks":

> About twenty years since I made several haemostatical experiments on dogs; and six years after repeated the same on horses and other animals, in order to find the real force of the blood in the arteries: at which time I wished I could have made similar experiments to discover the force of sap in vegetables; but dispaired of ever effecting it, till about seven years since, by mere accident I hit upon it, while I was endeavoring by several ways to stop the bleeding of an old stem of a vine, which was cut too near the bleeding season, which I feared might kill it. Having, after other means proved ineffectual, tied a piece of bladder over the transverse cut of the stem, I found the force of the sap did greatly extend the bladder; when I concluded, that if a long glass tube were fixed there in the same manner, as I had done before to the arteries of living animals, I should thereby obtain the real force of the ascending sap in that stem, which succeeded according to my expectation: and hence it is that I have been insensibly led on to make farther and farther researches by variety of experiments. . . . March 30th at 3 p. m. I cut off a vine on a western aspect, within seven inches of the ground; the remaining stump had no branches: it was four or five years old, and ¾ inch diameter; I secured the joint with stiff cement made of melted beeswax and turpentine, and bound it fast over with several folds of wet bladder and packthread: I then screwed a second tube to the first, and then a third to 25 feet height. The stem not bleeding into the tube, I filled the tube two feet high with water; the water was imbibed by the stem within 3 inches of the bottom, by 8 o'clock that evening. In the night it rained a small shower. The next morning at 6 and ½, the water was risen to three inches above what it was fallen to last night at eight o'clock. The thermometer which hung in my porch was 11 degrees above the freezing point. March 31 from 6 and ½ a. m. to 10 p. m. the sap rose 8 + ¼ inches. April 1st, at 6 a. m., thermometer three degrees above the freezing point, and a white hoar frost, the sap rose from 10 o'clock last night 3 + ¼ inches more; and so continued rising daily till it was above 21 feet high, and would very probably have risen higher, if the joint had not several times leaked: after stopping of which it would rise sometimes at the rate of an inch in three minutes, so as to rise ten feet or more in a day. In the chief bleeding season it would continue rising night and day; but much more in the day than night, and most of all in the greatest heat of the day.

In his next experiment he substituted a U tube mercury manometer for the glass tube and secured a pressure of 32.5 inches of mercury, or 43 feet of water. He conducted numerous experiments on root pressure, but the data he secured, important as they were, were probably exceeded in value by the techniques he introduced. The quaintness of his language in the above passage does not obscure his careful observations, his recording of all factors which might be of possible importance in interpreting his results, his constant use of quantitative measurements and his clear, concise descriptions—all innovations in the study of plants. Nor have his experimental techniques been greatly improved even to-day.

Hales summarizes his extensive experiments on water conduction as follows: "These last experiments all show, that although the capillary sap-vessels imbibe moisture plentifully; yet they have little power to protrude it farther, without the assistance of the perspiring leaves, which do greatly promote its progress." Here was a theory of sap rise which, despite its reliance on capillary action, came nearer to the modern cohesion of water theory than anything else ever proposed.

Of Hales's other work on water relations of plants perhaps the most important was his demonstration that there is no circulation of sap and that the path of water was upward through the wood. He gave the correct explanation of the cessation of bleeding after leaves form. He noted that water absorption decreases daily in cut branches, and that the former rate could be partially restored by cutting a fresh surface.

Hales devised methods of determining the distribution of growth similar to those employed to-day. He spaced pins in a row on a handle to measure growth distribution in stems, and in squares on a square of wood to measure leaf growth. By dipping the pins in red lead and oil he was able to mark the stems or leaves and follow their growth. His theory of growth was not so satisfactory. He believed that air and sap pressed on the shoot with sufficient force to cause growth, and tried to relate growth to the imbibitional forces he observed in swelling pea seeds.

He was the first to suggest that air is involved in plant nutrition, and might have discovered photosynthesis had chemistry not been so undeveloped, but he could not progress beyond the following vague concepts:

> Plants obtain nourishment not only from the earth but also more sublimed and exalted food from the air, that wonderful fluid, which is of such importance to the life of vegetables and animals. . . . For the air is full of acid and sulphurous particles which, constantly forming in the air, are doubtless very serviceable in promoting the work of vegetation; when being imbibed by the leaves, they may not improbably be the materials out of which the more subtle and refined principles of vegetables are formed. . . . We may therefore reasonably conclude that one great use of leaves is to perform in some measure the same office for the support of vegetable life, that the lungs of animals do for animal life; plants very probably drawing thro' their leaves some part of their nourishment from the air. . . . May not light, which makes its way into the outer surfaces of leaves and flowers, contribute much to the refining of substances within the plant?

Here speculation replaces the experimental evidence characteristic of his work on water relations, though it is interesting to note that he delayed the publication of "Vegetable Staticks" two years in order to conduct numerous experiments in which he subjected miscellaneous vegetable and animal substances to distillation, fermentation, acids, and so forth, collecting the gases produced over water. These experiments provided the basis for his statement that the substance of plants might be partly derived from the air.

Stephen Hales's other field of investigation in botany was reproduction, but here he contributed nothing of value. His theory was similar to Grew's and was briefly as follows: sulfur attracts air, farina (pollen) abounds in sulfur and so unites with the air inspired at several parts of the plant, especially the pistillum; it is then conveyed to the capsula seminalis where light is added, and thus the three most active principles in nature are combined to form a punctum saliens to invigorate the seminal plant. What a striking example this is of the results secured when conjecture replaces experimentation! Here Hales's work belongs to the botany of the fifteenth century; his work on water relations belongs to that of the twentieth.

Hales also made several contributions to gas chemistry and invented the pneumatic trough, which made possible modern advances in the field, although this is usually credited to Joseph Priestley. Indeed, some of his biographers rank his chemical work on a par with his physiological work, though this hardly seems justified. From the standpoint of the scientist, and especially the botanist, it is extremely unfortunate that at the height of his scientific fame he practically deserted his work in pure science for other interests. At this time he was only fifty-six years old and had twenty-nine years of life ahead of him.

He became a trustee of the Colony of Georgia, a position which he filled until near the end of his life. This public service required much of Hales's time and energy. That his efforts did not go entirely unappreciated is indicated by the fact that the naturalist governor of the Colony, John Ellis, named the genus *Halesia* (Silver Bell) in his honor.

His scientific interests had now turned

to applied science and invention. In 1739 he published a volume, entitled "Philosophical Experiments," describing numerous inventions and applications of science to human welfare. Between then and 1756 he published four other similar volumes. His work included such diverse subjects as methods of dissolving the calculus or kidney stone, ventilation, improved methods of distilling fresh from salt water, preservation of water and meat on sea voyages, methods of cleaning harbors, deep sea gauges, use of furze in fencing river banks, methods of preventing the spread of fires, thermometers for high temperatures, natural purging waters, preserving corn from weevils by fumigation with brimstone, salting meat by passing brine through the arteries of the uncut animal, earthquakes, keeping gun powder dry at the mills, and freeing mines from asphyxiating and explosive damps.

His work in applied science was inferior to his work in pure science, and few of his inventions were actually of practical value. His favorite invention was his ventilator and, together with his crusade against gin, held the major part of his attention during his declining years. He believed in ventilation for plants as well as humans, and when the Princess of Wales was having a greenhouse erected at her Kew Gardens she asked him to install a ventilator in it.

In 1739 he had received the Copley Medal of the Royal Society. Ironically enough, it was for his research on the calculus, according to Clark-Kennedy "the least successful and credible of all his scientific work." In 1753 he was elected one of the eight foreign members of the French Academy. In 1756 he conducted his last recorded experiment, returning once more to pure science. He studied the effect of blowing air through a bucket containing several fish, with a similar bucket of fish as a control. He also investigated the nature of gill breathing.

When Stephen Hales died in 1761 a memorial was erected to him in Westminster Abbey, but he had expressed the wish to be buried under the porch of his church at Teddington. His epitaph, long since worn away, has been reproduced on a brass plate erected on the nearby tower by a group of botanists in 1911.

That this was done by botanists was most appropriate, for despite Stephen Hales's varied activities and the fact that his active botanical researches extended over only about twenty years of his long career, his most lasting claim to fame rests on his work in botany. Only his work in animal physiology approaches in importance his contributions to botany. In animal physiology he was contributing to a science already well established by the work of Harvey and others; in botany he himself established plant physiology as a definite phase of science. With the possible exception of the isolated and rather meager work of Cusanus, Boehm, Van Helmont and a few others, he introduced an entirely new approach and new methods and techniques in the study of plants: the use of physical and chemical principles in the explanation of plant processes, the use of carefully conducted and controlled experiments as the source of information about plants, and the use of various measuring devices which put the new science on an accurate quantitative basis from the start. Nor was this all: he did his work so well that few of his results have been invalidated by modern research. His studies in water relations, to which he devoted most of his attention, provided much of our fundamental knowledge in this field and are occasionally referred to even in modern textbooks, not as curiosities, but as sources of information.

The historians of botany have almost universally accorded him praise, in striking contrast to the severe criticism many of them have directed against his

more widely publicized contemporary, Linnaeus. Several historians express the opinion that Linnaeus, through his widely accepted artificial system of taxonomy, retarded the development of a natural system of taxonomy as much as a century. No similar charges are directed against Hales. The nearest approach to an adverse criticism of Hales is the following passage by Green:

> Great as was the advance that Hales made from the standpoint of Grew, he did not attain anything like the modern position of physiologists. If we study his writings with greatest care we fail to find in them any recognition of a living constituent of the plant dominating its various mechanisms. The sap seems to be the all-important thing, and its movements, its refinement under the influence of light, and its various fermentations take the place that is now given to the living substance. Hence his explanations of physiological phenomena were purely mechanical. The vagueness of Grew is not entirely absent; we find him saying of light that "it contributes to the ennobling of vegetables." His knowledge of the functions of the various organs of the plant was naturally in many respects imperfect—we can only wonder that it was so extensive, for those were still the days of the infancy of chemistry as well as of physiology.[5]

Hales seems to have had a dualistic concept of plant processes: he believed that certain processes ("staticks") could be explained entirely by physical and chemical principles, while others (vital) could not be explained by science. Sachs points out that, "Permeated with the spirit of Newton's age, which notwithstanding its strictly teleological and even theological conception of nature did endeavor to explain all the phenomena of life mechanically by the attraction and repulsion of material particles, Hales was not content to give a clear idea of the phenomena of vegetation, but sought to trace them back to mechanico-physical laws as then understood."[6] Hales's freedom from teleological explanations is indeed remarkable, and he used terms with teleological implications only rarely. Sir Francis Darwin's comments in this connection are of interest:

> Whewell points out in his "History of the Inductive Sciences" that the physiologist asks questions of nature in a sense differing from that of the physicist. The *Why?* of the physicist meant *through what causes?* and that of the physiologist *to what end?* This distinction no longer holds good, and if it is to be applied to Hales it is a test which shows him to be a physicist. For, as Sachs shows, though Hales was necessarily a teleologist in the theological sense, he always asked for purely mechanical explanations.[7]

Another aspect of Hales's work which receives favorable criticism from the historians is his aptness at experimentation and the cleverness of his experimental techniques. Hales introduced into plant physiology the processes of weighing and measuring, leaving nothing to vague assertion or inaccurate estimation. Nordenskiöld comments: "In his ability to organize biological experiments and draw conclusions therefrom he was excelled by none of his contemporary scientists and by but few of those that have come after him; it has been possible even in modern times to apply his experimental methods with profitable results."[8] In a similar vein Darwin points out that, "His successors have discovered much that was hidden from him, but consciously or unconsciously they have all learned from him the true method and spirit of physiological work."[9]

That Hales fully appreciated the method and spirit of science is indicated by the following passage from the Preface to his "Haemastaticks":

> Though we can never hope to attain to the complete knowledge of the texture, or constituent frame and nature of bodies, yet may we reasonably expect by this method of experiments, to make farther advances abundantly

[5] J. R. Green, "A History of Botany," p. 203, London, 1914.

[6] "History of Botany," p. 477.

[7] Sir Francis Darwin in "Makers of British Botany," F. W. Oliver, ed., p. 67, Cambridge, 1913.

[8] Erik Nordenskiöld, "The History of Biology," p. 253, New York, 1932.

[9] "Makers of British Botany," p. 68.

sufficient to reward our pains. And though the method be tedious, yet our abilities can proceed no faster; for as the learned author of the "Procedure of Human Understanding" observes, "All the real true knowledge we have of nature is entirely experimental, insomuch that, how strange soever the assertion seems, we may lay this down as the first fundamental unerring rule in physics, That it is not within the compass of human understanding to assign a purely speculative reason for any one phenomenon in nature." So that in natural philosophy, we cannot depend on any mere speculations of the mind: we can only with the mathematicians, reason with any tolerable certainty from proper data, such as arise from the united testimony of many good and credible experiments. Yet it seems not unreasonable, on the other hand, though not far to indulge, yet to carry our reasonings a little farther than the plain evidence of experiments will warrant; for since at the utmost boundaries of those things we clearly know, there is a kind of twilight cast from what we know, on the adjoining borders of *terra incognita*, it seems therefore reasonable in some degree to indulge conjecture there: otherwise we should make but very slow advances in future discoveries, either by experiments or reasoning: for the new experiments and discoveries do usually owe their first rise only to lucky guesses and probably conjectures, and even disappointments in these conjectures do often lead to the thing sought for: thus by observing the errors and defects of a first experiment in any researches, we are sometimes carried to such fundamental experiments, as lead to a large series of many other useful experiments and important discoveries.

CHANGES IN LAND UTILIZATION IN SOUTH SEA ISLANDS

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THE South Sea islands came to the attention of the people of the Western world at a time when the religious faith of Europeans was being specially stirred by Christianity. One result of this was the sending of Christian missionaries to these far-flung specks of land on the opposite side of the globe. The pioneer ship *Duff* of the London Missionary Society first reached Tahiti in 1797. It was not many years until all the Polynesian peoples, and most of the Melanesians of the South Seas, had adopted the new religion.

With the adoption of Christianity the brown-skinned peoples also took on clothes. Various other transformations in their ways of living took place. Among the last things to change were their methods of land utilization. Western methods of farming now being adopted mark the complete breakdown of native island civilization and a new method of life ill suited to the cultural values of the indigenous people.

The land in South Sea islands is held in large areas, each owned by an extended kinship group governed by a chief. The chief is an executive and designates certain areas to be worked by the families in his clan or tribe. In Samoa the *aiga* is the kinship group, ruled by a *matai*, or head, who directs its economic and political activities. In Fiji the *mataquali*, or clan, is the land-owning group.

For planted crops like taro, the more important crop in many islands, a clearing is made in the forest by girdling the trees or burning the bases of the trunks. Trunks and large branches are left lying on the ground. Dry brush is gathered and burned. Taro tops are stuck in holes made with the digging stick of the native. Taro plants in the clearings grow in various stages of development from slips a few weeks old to mature plants seven or eight months old.[1] Yams are planted

[1] See J. W. Coulter, "Land Utilization in American Samoa," pp. 25–27, Bernice P. Bishop Museum, *Bull.* 170, 1941.

by gathering the earth about cuttings and piling the soil higher as the tuber develops.

When two or three crops are raised, the clearing is abandoned. Another area is similarly cleared and the agricultural process is repeated. In the warm, rainy climate, trees and shrubs soon grow up again in the abandoned plot. In ten to fifteen years the soil has become rejuvenated, and after that time the natives go back to the erstwhile planted area, clear it over again and plant a new crop. It is a process of rotating the land instead of the crops. The cultivated plots are widely scattered. This is a form of primitive economy in which the amount of land needed for a small group of people is large.

No regular method of planting tree-crops is followed by the indigenous people. On many lands where coconuts grow the trees are a volunteer growth, sprung from nuts which have fallen. Bananas are usually planted in parts of the coconut plantations near the villages. There is no systematic planting of breadfruit trees, which grow for many years—Samoans do not know exactly how many. Besides furnishing one of the staple foods, the tree is extensively used on some islands for building native houses. Among several other tree crops, pandanus and paper mulberry are important; but they occupy a small part of the area used.

Large areas on islands are natural forest or bush, characterized by an extraordinarily luxuriant growth of vegetation. Epiphytes grow in the branches of trees and shrubs, and vines form masses over their stouter associates. The forest affords useful products without requiring any replenishment. Some of them are important as emergency foods, gathered after destructive hurricanes. The forest is most important in that it supplies lumber for making boats and houses; fiber for girdles and cord; wood for digging sticks and tapa beaters. Various kinds of flowers are taken from the forest to perfume coconut oil.

These methods of land use worked well because of the small density of population in South Sea islands, and a large area of agricultural land. When the United States took over American Samoa in 1900, the total population was 5,679 in an area of some 60 square miles, that is about 95 persons per square mile. In the Fiji Islands in 1881 the native population was 114,748, and the total population 127,486. Those islands have a total area of 7,083 square miles.

In the early days there were certain checks on the increase in population which kept the numbers of people in the islands at about the same figures. Frequent tribal wars took their toll of native lives. There was a very high infant mortality rate because of unsanitary surroundings and ignorance of child hygiene and nutrition.

This method of land utilization fitted in with the culture and environment of the people. It was an indifferent and irregular kind of cultivation. In the native scheme of food production no one was called on to labor diligently and regularly. All were fed and sheltered with plenty of time left over for social gatherings, recreation and lying in the shade. No one lived below a comfortable subsistence level. There was scarcely any time when frugality and thrift were necessary.

Each day had its own schedule, which was not known until the morning or perhaps the evening before. Samoans still rise before daylight and do their hard work before the sun is high. After their labors, they return to the village and have a light meal; during the afternoon they rest, stretched on mats in their homes. The main meal of the day is eaten about sundown.

Methods of land utilization were not the best adjustment to the native's natu-

ral environment, but they were adequate. They involved no problem of note which was forced upon his attention. Every one was satisfied and there was no incentive to progress in the western sense of the word.

On many islands land is now owned in fee simple by individuals and registered under their names in the land office of the government. We can find blue prints with the boundaries marked exactly, just as in a land office in the United States.

Systems of land tenure are similar to those in Europe and America. We find land leased by one native to another. Land is inherited by a son from his father under the English system of primogeniture.

Natives carry on small farming, raising several crops, some of them "money crops." In the *malae*, or public square, in Pago Pago in American Samoa there is a market day once a week. In the Pago Pago Bay district the Samoans are supported in part by a commercial economy. There is a lively little trade in taro, bananas and other products from outlying villages. Native commerce has become part of a world economy.

Many Fijians have renounced their time-honored methods of agriculture and become peasant farmers. This has meant separation from their old cooperative communal ties, and psychological transformation into individualists. A Fijian wishing to become a peasant farmer can secure an official exemption from the communal duties which fell to his lot as a member of a native village community. The government arranges for the successful applicant to have a lease on ten acres of land for ten years. Fijians raise sugar cane, bananas and rice and sell them. In some parts of the islands one sees them plowing with horses.

I was a guest of the Fiji Department of Agriculture to the Central part of the island of Viti Levu where, in the Waindina basin, members of hill tribes of Fijians have been established on small farms to raise bananas. They like this crop, for it requires little work. They are on government land which was leased to them rent-free for the first two years, and after that for a small sum. They raise a variety of Cavendish banana which takes about ten months to mature. Agricultural officers and assistants visit the district regularly, inspect the plantings, supervise the harvesting and packing of the fruit, market it and pay the natives. The fruit is transported by river to Suva on bamboo rafts which the natives call "no come back" boats. At Suva the rafts are broken up and sold and the boatmen walk home.

Various other crops are raised by Fijians who attempt to raise produce for a market. Market gardening is carried on by natives living near Suva. They raise vegetables for the local English market: cabbages, cauliflowers, lettuce and tomatoes. The mobilization of troops in Suva and the presence of soldiers from New Zealand have enlarged the market. Natives on the island of Kandavu raise similar vegetables and ship them in their small boats to Suva. There are native growers of citrus fruits, papaias and avocadoes.

There are several reasons for the changes from the ancient traditional ways of land tenure and land use to modern, Western methods.

The population of various islands has multiplied and has increased the pressure on the land for means of subsistence. The population of American Samoa is now 12,908 compared with 5,679 when the United States accepted the cession of the islands. The increase in population is due in part to the fact that a Western government established an era of peace in the islands. A much more important factor in the increase is the establishment of a régime of medical service and sanitation, the extent of which, in view of the small number of

the total population, is scarcely to be found elsewhere among a native people. A Department of Public Health was established in American Samoa in 1914. Medical service in the group of islands is entirely free. The thing which Samoans need most is being supplied by the government. The change in native economy itself has also been a factor in the increase of population.

The population of Fiji is now 220,787, nearly twice as much as it was in 1881. This has meant more intensive use of the land.

However, an important reason for the change in Fiji was the immigration of East Indians as indentured laborers on sugar-cane plantations and later their establishment as peasant farmers.[2] The time-expired Indian immigrant rarely sought reengagement as a plantation laborer. On the completion of his term of indenture he had little difficulty in leasing from native or from European owners sufficient land for his requirements; and was able by the cultivation of rice, corn or other crops for which there was a small market to ensure a sufficient and not too arduous means of livelihood for himself and his family.

In 1921 and subsequent years the Colonial Sugar Refining Company of Fiji established its plantation laborers on its lands as lessees, the company paying its tenants for the amount and quality of the sugar cane produced.

The regular work of Indian farmers in Fiji is in contrast to the irregular, easy-going life of the Fijians. The oriental rises at half past five in the morning and works at intervals until sundown; resting for awhile, however, during the hottest time of the day.

During the past two decades the government of Fiji has noted with concern the rapid increase in the population of Indians and the development of the agricultural resources of the islands by their methods of peasant farming. Indians have secured more and more land on leases from the Fijians, and many have employed natives to work for them.

The present director of agriculture, shortly after assuming the duties of his office, realized that little progress had been made in the development of modern agricultural methods by the Fijians, and that the formulation of some kind of policy by the government was essential to help the Fijians hold their own, economically speaking, in the islands. He has been the first to introduce and carry out a well-defined agricultural policy for the natives. The objective of the policy is the establishment of the natives as peasant farmers something like the Indians. But the problem is how to achieve this on behalf of a race which still preserves a strongly communal organization.

Another reason for the change in methods of land use is contact with western people. Europeans in the islands hold land in fee simple and farm it according to their own methods. This is the case in British Samoa and in Fiji.

In American Samoa I observed that a chief on an outlying island was insisting that plots of land be worked by families rather than communally. Although no land on his island was owned by any one in fee simple, it seemed that he was anticipating what was going to occur in the future.

American Samoans have been brought into close contact with our culture on the island of Tutuila. There are some 45 miles of secondary roads on that island, and the amount of travel on them helps to disseminate the westernized ideas of natives about Pago Pago Bay, who, for many years, have been closely associated with our Navy. Busses run between villages and the Naval Station. Many come in from outlying districts in the islands on steamer days to sell their wares to tourists.

[2] See J. W. Coulter, *Proc. 6th Pac. Sci. Congress*, Vol. IV, pp. 29–37, 1939.

The necessity for money is a reason for commercial agriculture. South Sea natives must purchase the minimum of clothes that they wear. Cotton takes the place of the old-time bark cloth, or tapa, which is now used only on ceremonial occasions. Men wear kilts (*lavalava* in Samoa) folded about the waist, and a good many wear shirts also. Women wear kilts and blouses. Shoes are not worn. Almost every village in Fiji has at least one hut with a galvanized iron roof. The iron must, of course, be purchased, and nails also.

The lack of markets for "money crops" has deprived many of them of the small incomes necessary to buy the few things for which they must have funds. The very low prices offered for copra—for so long a dependable cash crop of South Sea Islands—has been very discouraging. Their houses remain unlighted in the evenings, for they have no money to purchase kerosene for their lamps. When I visited a village on Viti Levu Bay, the only thing the people wanted in exchange for bananas was lamp oil. Some Fijians have gone back to the use of an improvised wick in coconut oil, expressing it themselves in a crude way from their unsold copra. Some make more native bark cloth from mulberry, for they can't buy cotton.

The increased population in South Sea Islands makes it necessary to use the clearings more often, and there is no longer opportunity for the soil or the forest to recuperate. In the mountainous country of American Samoa and Fiji a serious result of the repeated use of forest clearings for agriculture is soil erosion.

Under the new system of agriculture, soil conservation is a necessity which did not arise on account of their old methods. Forest and brush soon grew again in the clearings and held the soil in place, so soil conservation never became a problem. It is, therefore, difficult for a farmer to realize that if his land is continually cropped, methods of retaining the soil and rejuvenating it must be practised. Decreasing yields are a serious concern. He has never known the use of fertilizer, and crop rotation is an idea which has no meaning for him. The rapid washing away of soil even on gentle slopes is especially discouraging. The effect of the running water is much increased by an accepted practice of native farmers of making their rows up and down slopes instead of sideways along the contours.

The change to individual farming does not fit in with the philosophy of South Sea natives. The idea of being alone, independent and non-cooperative generally in his dealings with fellow men is not part of the social psychology of the indigenous people of the South Seas. And so many farmers yearn for the old life in a village community. They forsake their individual holdings and drift back again to be among their relatives and former friends. In 1930 the Colonial Sugar Refining Company at Labasa in Fiji placed twelve young Fijians on ready-made sugar-cane farms. As the years passed they became discouraged with the new type of life. One by one they drifted back to their villages, and when I visited the district in 1941 only one of them still remained on his farm. The company has had similar experiences in other districts.

It is significant that in the Census of 1936 there are no Fijians listed as storekeepers or traders. Trading by the natives has never been successful; a few attempts at forming merchandising companies have resulted in complete failure. The native storekeeper can not resist demands for credit, and soon his relatives, friends and neighbors have borrowed all his stock and he is obliged to go out of business. The urge to carry on the old communal generosity can not be reconciled with individualistic efforts.

The result of individualistic ventures is that the old Fijian social system is rapidly breaking down. The Fijian communal system for many years weathered the impact of our type of civilization; but it seems destined not to survive much longer, at least without considerable modifications.

The problem faced by South Sea Island governments is the stabilization of native character during the transition from communal life to whatever system replaces it. Dwarfed and condemned by individualism, the communal social system has begun to crumble and disintegrate, especially where the impact of the more self-assertive culture is strongest. This in the face of well-intentioned, if at times half-hearted, efforts to protect and conserve what is best for the good of the untutored majority as yet unfitted for any radical change in their society.

The attitudes of governments towards natives of South Sea Islands under their influence has remained essentially an economic one. To make the best commercial use of land is uppermost in the minds of American and British farmers, and this is reflected in the attitudes of their governments towards agricultural production. However, there is no evidence that the economic system of western civilization can be imposed on a native people with advantage to them.

Attributes of character of the natives of South Sea Islands which make it very difficult to adjust themselves to western culture can be traced to the environment in which their type of society has developed. A native's "knowing" things must be defined as a manner of reacting to his environment; his world is an isolated island where nature has been kind.

I close by saying: "Let me beg that we take an objective attitude toward ourselves, and look with humility upon the beliefs and attitudes which we cherish with such vehemence. Having achieved this end, we can react with sympathy and understanding towards the minds of others whose differing racial background, national history, social status or economic security give them an equally different outlook on life."[3]

[3] A. T. Poffenberger, SCIENTIFIC MONTHLY, July, 1933.

THE BOUNDARY OF LIFE

WE have known since Pasteur that there are two ways of poisoning the body—with a deadly chemical poison like arsenic or cyanide, and with a living infection like the bacillus of typhoid or tetanus. The difference between them is that the chemical poison has a direct effect only. Its action is proportionate to the original amount of the dangerous substance that touches or gets into our bodies. The living infection, on the other hand, may attack us as a single particle, but once it gets inside the body it can multiply without limit until it kills us and perhaps spreads to our neighbors and kills them.

There is no difficulty about this distinction, but in the last forty years a new borderline class of agents has gradually been recognized: the viruses. They are chemical compounds which are capable of crystallization, as Stanley found in 1935. But nevertheless they multiply within the body and can spread like any other plague. Are they living or non-living? It is useless to ask, for they themselves prove that the boundary between the living and the non-living is an artificial one. Now these viruses cause measles in man and foot-and-mouth diseases in cattle, and a hundred other dangerous but curable diseases of men and animals. But when they attack plants the disease is always incurable. They attack most cultivated plants, particularly those of the group to which the American crops tobacco, tomato and potato belong. And they are transmitted in a great many different ways —in every way except the obvious one of the seed. The gardener who is raising tomatoes has to take care not to smoke when he is tending his plants, or he may infect the tomatoes with a tobacco virus.—"*Monthly Science News,*" *March, 1942, Canada.*

CONTINENTAL GLACIATION HYPOTHESES BEFORE LOUIS AGASSIZ

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AMERICAN geologists have accorded Louis Agassiz outstanding recognition for his interpretation of the significance of glacial phenomena, but physical evidences of glaciation puzzled the natural scientists long before his arrival in the United States. Without detracting from the accomplishment of Agassiz, it should be noted that his glaciation theories had been postulated to a considerable extent by foremost American scientists of the early nineteenth century. His contribution climaxed a discussion which had intrigued academic circles for some time before 1846, the date of his arrival. By tracing the history of this discussion through a half century, it is possible to note changes in scientific thought, especially in the field of geology.

Field observations of glacial debris in the northeastern states date from the last decade of the eighteenth century, when, in 1793, Benjamin DeWitt, a New York physician, published an account of erratics strewn along Lake Ontario shores. He attempted to account for their occurrence and distribution.[1] DeWitt and many who followed him were convinced that the position of such boulders was due to transportation by action of currents of water flowing over the surface of the land. This hypothesis, later known as the diluvial theory, proposed two explanations for the cause of the streams.

The first, and most logical idea, in view of the trend of scientific opinion, was that the deluge as described in Biblical accounts was a sufficient transporting power. A second hypothesis, simply conceived, accounted for streams or ocean currents overflowing the continent because of complete submergence of the land mass, but such a proposal involved the difficult problem of explaining such extensive submergence. Variations of these two themes called for shallow rivers flowing over the continent or greater development of ocean currents on a submerged land mass. Absurd suggestions included destruction of a huge barrier around the Great Lakes, releasing flood waters over large areas. Another scheme involved tectonic disturbances in the Arctic in order to explain changes of temperature with consequent melting of large ice masses. In all these theories the authors were careful to conform to the story of the deluge. Obviously some of these hypotheses were based in part on flights of fancy, rather than on factual observations.

H. H. Hayden, a Baltimore dentist who was interested in geology, published his "Geological Essays"[2] in 1820; this was the first serious consideration of glacial theory in scientific circles of the United States. Hayden's imagination supplied floating ice as an agent for transporting erratics. To him goes the honor for the first suggestion of ice action, though he did not realize the full import of his idea. Benjamin Silliman, professor of chemistry and natural history at Yale, in a notice of Hayden's book,[3] supported the author's views but expressed regret for the fanciful explanations of natural phenomena.

The most important exponent of the diluvial theory was Henry Darwin Rogers, professor of geology and mineralogy

[1] George P. Merrill, "The First One Hundred Years of American Geology," p. 615, 1924.

[2] Baltimore, 1820.

[3] *American Journal of Science and Arts*, 3: 47–57, 1821.

at the University of Pennsylvania, who directed the geological survey of New Jersey and Pennsylvania in 1836. On numerous occasions he expressed his opinion on the subject of the deluge. In his discussion of the origin of Niagara Falls, he ridiculed the idea of a seven-mile recession of the cataract by means of normal erosion processes.

> The whole of this region has been grooved and scarified by the same far-sweeping currents which denuded the entire surface of North America, and strewed its plains and mountains with boulders, gravel, and soil from the North. Such a diluvial valley, of greater or less depth was, I cannot help believing, probably the commencement of the present remarkable trough below the Falls.[4]

On numerous subsequent occasions he affirmed his belief in the validity of the diluvial theory, long after most American geologists were converted to Agassiz' theory of glaciation.

Edward Hitchcock, as state geologist of Massachusetts, subscribed to the tenets of the diluvial hypothesis. Other supporters included C. T. Jackson, state geologist of Maine and Rhode Island, and Charles Whittlesey, of Cleveland, who attributed the glacial terraces along Lake Erie to deposition by ocean currents.[5] George E. Hayes wrote, in 1839, "Can proof be more conclusive that these marks and scratches were produced by gravel, stones and boulders, swept over the surface of the rocks by currents, tides, or waves, which flowed from the north?"[6] William C. Redfield, astronomer, and first president of the American Association for the Advancement of Science, believed the presence of striae and positions of erratics were due to scarification and transportation by ocean currents and that their formation and deposition occurred during submergence, as their courses agreed with those of the ocean currents.[7] William Barton Rogers, brother of Henry D. Rogers, who served as professor of physics and chemistry at William and Mary College and the University of Virginia and who was placed in charge of the geological survey of Virginia in 1835, also supported the diluvial theory.[8]

Some of the most outstanding geologists in the country were convinced of the truth of the diluvial theory, and declined to agree with the views of Agassiz. Furthermore, the suggestion had already been made, a quarter-century before his arrival, that ice *and* water were responsible for the distribution of glacial debris throughout the northern states.

The diluvial hypothesis, despite its general acceptance, failed to satisfy some of the observed phenomena. Its enthusiasts offered no satisfactory explanation of polished rock surfaces or striations, and there were other serious inconsistencies between hypothetical and observational data. Chester Dewey, later professor of chemistry and natural philosophy at the University of Rochester, challenged the theory seven years before the arrival of Agassiz: "The friction of the water and earth in the Genesee wears somewhat smooth surfaces on the same rock, but nothing like the polished surface [noted in the field]. What is the power or cause which could have moved any hard body so as to have produced this result?"[9]

Ebenezer Emmons, geologist-in-chief of the second district of the Geological Survey of the State of New York, questioned the efficacy of water as an agent capable of moving quantities of soil and rocks from their original positions. In a report on two ore beds in the region south of Lake Champlain, he considered the possibility that their positions had been shifted southward by some unknown force.[10] The nature of such a

[4] *Ibid.*, 27: 326–335, 1835.

[5] *Ibid.*, 60: 31–39 (second series, vol. 10, 1850).

[6] *Ibid.*, 35: 191, 1839.

[7] *Ibid.*, 47: 120–121, 1844.

[8] *Ibid.*, 43: 180–181, 1842.

[9] *Ibid.*, "On the Polished Limestone of Rochester," 37: 242, 1839.

[10] New York Geological Survey, Fourth Annual Report of the Second Geological District, 1840, p. 313.

transporting agent was left in doubt, and Emmons was satisfied with a mechanical-religious explanation as if hesitant to express his true ideas on the matter. In support of the challenge to the theory he noted an apparent inconsistency between the time when striations occurred and the nature and extent of alluvial deposits overlying them.

In 1844, Edward Hitchcock joined the ranks of the dissenters, and expressed his conviction that the diluvial theory was inadequate, basing his conclusions largely upon the inability of water to produce the polished limestones which he had observed near Rochester.[11]

It may be noted that the changed point of view, and the trend of scientific opinion away from the diluvial theory were coincidental with beginnings of field observations for the state geological surveys. Those who made studies of the drift gradually came to see the need of an adequate causal explanation for the presence of glacial features in the landscape.

As the diluvial theory was found wanting, the second important concept was proposed to account for drift phenomena. It originated in 1837 or earlier with Peter Dobson, of Vernon, Connecticut, and became known as the iceberg hypothesis.[12] He suggested that large masses of ice from Arctic regions had floated southward, carrying rocks and gravel which were transported over the submerged continent and dropped in their present positions when the icebergs melted. The catastrophic origin of such bergs was doubted, but critics of the theory admitted that combined action of *ice and water* provided an explanation for observed glacial drift, striae, potholes and moraines. The whole question of the action and movement of icebergs was opened for discussion as the result of Dobson's thesis. Lengthy papers were written and much research on problems of glacial behavior took place.

John Lord Hayes, later chief clerk at the U. S. Patent Office, advocated the efficacy of icebergs and glaciers in transportation of material in an important paper presented before the American Association of Geologists and Naturalists.[13] The action of ice was stressed also by W. W. Mather, superintendent of the Ohio Geological Survey. He became the principal proponent of the iceberg theory, for it permitted him to account for field observations. He declared against the ideas of Agassiz, finding the concept of extensive glacial action in non-mountainous regions untenable.[14]

If proponents of the diluvial theory had trouble defending their views, J. L. Hayes and W. W. Mather had to meet more serious objections to their iceberg theory. Emmons gave three reasons for its rejection: it failed to explain polished rock surfaces; it did not account for uniform direction of striae; it failed to provide for the great age of the striae. His attempt to reconcile fact and theory appears in his statement:

> Is there any connection between the pot holes and the abrasions of the sandstone? We know the former could not have been produced by an iceberg, and probably not by the deluge, but we know they are the effects of running water. There may be a connection but it is not possible to demonstrate it. Both phenomena have the appearance of having been produced by one agent, but we are wanting in fact. . . .[15]

Hitchcock objected to the iceberg theory, chiefly because of the lack of explanation of low temperatures to produce glaciers and bergs.[16] In its place, he proposed the glacio-aqueous or aqueo-

[11] Association of American Geologists Report, 1844, pp. 45–49; 164–221.

[12] *American Journal of Science and Arts*, 46: 169–172, 1844, and Merrill, *op. cit.*, 619.

[13] *American Journal of Science and Arts*, 45: 316–319, 1843.

[14] "Geology of New York," First District, part 4, pp. 158–228.

[15] *Loc. cit.*, 313.

[16] First Anniversary Address before the Association of American Geologists, *Am. Jour. of Science and Arts*, 41: 256, 1841.

glacial theory, named to accord with the principal agent of deposition, ice or water. This hypothesis involved the use of ocean currents and icebergs, with an undetermined amount of glacial action, depending on the viewpoint of the individual. The combination of diluvial and iceberg theories effected a more ready acceptance of Agassiz' glacial theory. The combined theories were embraced by the more conservative American geologists, who admitted the force of Agassiz' arguments, but were reluctant to recognize the similarity of American and European drift phenomena. Hitchcock led the way, and in his anniversary address before the second annual meeting of the Association of American Geologists, he announced, "Henceforth glacial action must form an important chapter in geology." He recognized the validity of a glacial origin for all details of the landscape which had been unsatisfactorily explained by preceding theories, and he accepted Agassiz' ideas so completely that he was widely misquoted as an active supporter of the glacial theory in spite of the following statement: "To account for all the phenomena in this country, we want currents of water to flow over a large part of the surface, loaded with ice and detritus, for centuries at least."[17] At the following meeting of the association, he led a discussion on drift phenomena, and there acknowledged his indebtedness to Louis Agassiz, although he was convinced that an unmodified glacial hypothesis was not acceptable in America and failed to meet American conditions.

Within a short time, other geologists grew enthusiastic over the glacio-aqueous theory of Hitchcock. Chester Dewey, a supporter of the diluvial theory in 1839, stated four years later that in his opinion the position and appearance of glacial erratics in western New York seemed to require a combination of large masses of ice and a strong flow of water from the west of north to provide for their transport.[18] By 1844, Emmons was converted to the glacio-aqueous theory as the result of his careful studies of the Lake Champlain area. William Redfield, W. W. Mather and others soon stated their preference for this hypothesis, and thus made easy the acceptance of Agassiz' proposals.

Attempts to survey conditions in the field and increasingly acute interest in field surveys are apparent in a series of questions devised by geologists working under Mather's direction in the New York survey. Among others, these pertinent queries appear:[19]

> Where ledges of rocks have been recently uncovered by excavations, are the surfaces smooth, as if by the action of running water, or with pot holes, such as are seen at many water falls?
>
> Do any of these surfaces show grooves and scratches as if hard masses had been dragged over them?
>
> Are any large rounded or irregular masses of rock found in your neighborhood?
>
> Are there scratches on them in one or more directions?
>
> Are the rocks similar to ledges of rock known to you?

These leading and significant questions indicate a tendency toward field observation as a basis for geologic hypotheses, and the beginning of field techniques.

The glacio-aqueous theory was not intensely opposed by any American scientist except H. D. Rogers. Its supporters could provide no satisfactory reason for the postulated low temperatures and submerged continent. It did, however, clear the road for the acceptance of the work of Agassiz.

The glacial theory need not be repeated here. Its conditions were so log-

[17] Association of American Geologists Report, 1843, p. 217.

[18] "Striae and Furrows of the Polished Rocks of Western New York," *Am. Jour. of Science and Arts*, 44: 146–150, 1843.

[19] "Queries Proposed by the Geologists of the New Survey of the State of New York," *ibid.*, 33: 124, 1838.

ical that they were quickly recognized as valid, since they accounted for drift phenomena which had been observed in field studies in this country. It went a step beyond the glacio-aqueous theory, for it eliminated the need for submergence of the continental mass. One important challenge was left unanswered by Agassiz: the reason for temperatures so abnormally low that continental ice sheets began their southward advance. That challenge has not been answered yet, after a century of research.

American recognition of Agassiz' theory began as early as 1839, when Timothy Conrad, one of the assistants in the preparation of the New York Geological Survey from 1838 to 1841, declared in favor of continental glaciation, and wrote in its defense,

> M. Agassiz attributes the polished surfaces of the rocks of Switzerland to the agency of ice, and the "diluvial scratches," as they have been termed, to sand and pebbles which moving bodies of ice carried in their resistless course. In the same manner I would account for the polished surfaces of the rocks in western New York.[20]

Conrad's conclusions were based upon his studies of paleontology as well as field work on the drift phenomena. His views and those of Agassiz were similar to the opinions of Lardner Vanuxem, geologist in charge of the third district of the New York Geological Survey. The published papers of these men had comparatively little effect, for it was not until the significant address of Edward Hitchcock in 1841, as previously noted, that public and scientific interest was genuinely aroused in the glacial theory.

Outspoken opponents of the work of Agassiz included C. T. Jackson, who derided the glacial theory as both fanciful and imaginary.[21] He wrote, "This country exhibits no proofs of the glacial theory as taught by Agassiz, but on the contrary the general bearing of the facts is against that theory. . . ."[22] Jackson was seconded by Jean Nicholas Nicollet, who had come to North America in 1832 to study physical geology and geography. His point of view was even more positive than that of Jackson, for he found it "impossible to conceive how the effects described by M. Agassiz to the moving glaciers could with propriety belong to them."[23] Chester Dewey,[24] Henry D. Rogers[25] and W. B. Rogers[26] also challenged the glacial theory, but the most serious objections were expressed by Edward Hitchcock. He required satisfactory evidence of low temperatures and the presence of ice sheets. He was unable to accept the idea of ice in motion without transportation by water, or that ice would be able to carry erratics from valley floors to higher levels.[27] Such questions had to be answered to the satisfaction of the American geologists before the theory of continental glaciation could be applied to conditions in this country. By 1850, Agassiz had been able to convince all the most conservative scientists of the validity of his hypothesis, and many of his former opponents went to his support.

The change in glacial theory that occurred within the half century from 1800 to 1850 began with completely catastrophic explanations of drift phenomena, progressed through a maze of partly acceptable theses, and emerged finally as the comparatively satisfactory proposal of Louis Agassiz. His views have endured, but more significant than changes in glacial theory were changes in research methods, with final emphasis placed upon the need for adequate field studies and hypotheses which met the conditions found in the field.

[20] "Notes on American Geology," *ibid.*, 35: 237–251, 1839.
[21] *Ibid.*, 45: 320–323, 1843.
[22] *Ibid.*, 43: 151, 1842.
[23] *Ibid.*, 45: 323, 1843.
[24] *Ibid.*, 44: 146–150, 1843.
[25] *Ibid.*, 43: 180–181, 1842.
[26] *Ibid.*
[27] *Ibid.*, 43: 396–398, 1842.

CHINESE CHEMICAL TERMS

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MELLOR has spoken of the close relationship of the nomenclature of a science to the science itself and quotes Lavoisier to say that "like three impressions of the same seal, the word ought to produce the idea and the idea ought to be a picture of the fact."[1] This close relationship, because of the ideographic nature of the language, is produced in the Chinese chemical nomenclature.

As against the twenty-six letters of the Latin alphabet, available to the American chemists for use in writing names for various chemical elements and compounds, the Chinese chemist has a much wider choice. There are thirty to forty thousand distinct written characters found in the standard dictionaries, of which, however, only four to five thousand are in common modern use as exemplified in the vocabulary of the present-day newspapers. Hence there is a wide choice available for the character whose meaning and method of writing will be most suitable as the name of the chemical substance in question.

During the fifty odd years of modern Chinese chemistry, there have been three tendencies in regard to chemical terminology. The first has been to continue the use of the English terms. Since all students studied English in the high school this plan offered little difficulty. However, as the curriculum steadily increased the amount of science teaching, difficulties were met with and there arose a demand for the teaching to use entirely Chinese terms.

Another tendency, especially in the early years of this century, was to borrow the Japanese chemical nomenclature. This had been well worked out, and many text-books were being translated from Japanese into Chinese. Moreover, the ease of learning Japanese, the written language of which uses many Chinese characters, and the large number of graduate students who went to Japan to study also influenced this tendency. But the rising tide of feeling against Japan's aggression has made such a plan unthinkable to patriotic Chinese.

The third tendency has been to study the various systems of nomenclature and carefully prepare a standardized list of Chinese terms. A committee was appointed by the National Government Bureau of Education, and in 1933 there was published a list of such terms and the methods to be followed in naming inorganic and organic substances.[2] The principles followed in the creation of this standard chemical terminology have been discussed by Adolph.[3] This standard terminology has been universally adopted throughout China.

Before discussing these terms it is necessary to say a word about the construction of written Chinese. The author's first introduction to Chinese characters was to that type which is called "grass" writing. It is very easy to look at this form and wonder how any one can make sense out of it (Fig. 1a). The simplicity and order which underlie Chinese writing, its precision and beauty are not apparent to the casual observer in this kind of writing. Similarly, the beauty inherent in written English as revealed by the printing of a gifted drafts-

[1] J. W. Mellor, "Modern Inorganic Chemistry," p. 51, 1925.

[2] Hwa Hsueh Ming Ming Yuan Tse; Chinese National Publishing Bureau, 1933.

[3] W. H. Adolph, *Jour. Chem. Ed.*, 4: 1233, 1927.

FIG. 1. "NORMAL PHOSPHATE"
CHARACTERS WRITTEN TO SHOW THE DIFFERENCES BETWEEN THE "GRASS STYLE" (a) AND THE "KAI STYLE" (b) OF WRITING.

man is not observed in the typical scrawl of most chemists. To see the Chinese character in its essential dignity look at the writing in the "kai" style (Fig. 1b). Here the formal is emphasized. It is this form which is used as the standard for schoolboys. Patient copying of the characters as written by the old masters is the most fruitful method to teach the artist-calligraphist a good style. This ability has always been rare and is becoming more so, for the use of the lowly fountain pen in the schools is displacing the Chinese brush-pen which is necessary for beautiful writing.

In the examination of the "kai" style the division of all characters into a "radical" and a "phonetic" is usually quite easily observed. The total number of radicals is two hundred and fourteen. Phonetics number about eight hundred and ninety,[4] and often give a direct clue to the sound of the character. Hence the terrifying complexity of the vast numbers of quite distinct characters is reduced by the analysis of their structure into the radical and phonetic, the total number of types of which is slightly over eleven hundred (Fig. 2).

The Chinese language is monosyllabic, that is, each character has its distinct sound of one syllable. Characters and their syllables are put together and built up to convey a precise meaning. Yet these built-up expressions are extremely short. Compare the length of the English term "the freezing-point depression," with the French "l'abaissement du point de congélation," the German "Gefrierpunktserniederung" and the short four-syllable Chinese expression, "ping tien chiang ti."

Chinese grammar is extremely simple and adaptable. There is a freedom that is astonishing to any one who has suffered from English grammar. Declensions of nouns, verb endings, verb tenses are all absent. Many verbs can be used without change as nouns. Singulars and plurals are oftentimes conveyed by inference or the sense of the connection. This gives great freedom in constructing new terms to express scientific concepts and ideas.

[4] W. E. Soothill, General Pocket Dictionary; Presbyterian Mission Press, Shanghai, 1928.

Modern Chinese seems to have greater adaptability than modern English. Certain scientific ideas are with difficulty expressed in English and require special terms based upon Greek or Latin words. The same ideas readily find expression in modern Chinese. It is a common experience of Westerners teaching in China to prepare examination questions which when translated into Chinese are a dead give-away. One examination question read, "to tell the difference between the structure of isotopes and isobars." But isotopes are translated as "similar number elements" and isobars "similar weight elements." The original question had lost much of its examination value. Such Chinese terms state the idea involved more clearly than do the English terms.

The above features of the Chinese language are shown in the discussion of a few scientific terms below.

1. *Science.* This is translated by a two-character term, "k'o hsueh." The first means a class, a series or rank; the second is to learn or to study. Hence the literal meaning of the translation is, *the study of classification.*

2. *Chemistry.* Another two-character expression, "hwa hsueh." Two verbs, the first, to change or to transform, the second to learn or to study, being combined to make a noun and meaning *the study of change or transformation.*

3. *Analysis.* "fen hsi," again two verbs combined, both with the idea of dividing, of splitting. This term may be used as either verb, noun or adjective.

4. *Qualitative.* "ting hsing," the first being to fix, settle, decide and the second is disposition, qualities or nature. Hence the *determination of qualities.*

5. *Isomorphous.* "tung hsing ti," the first character means identical, the second, form, figure or shape, while the third is body. So the combined meaning, *bodies of identical shape or form.*

In chemical nomenclature a simple method is used to differentiate between those elements which are gaseous, liquid or solid. The radical called "chi" denoting gaseous properties, is combined with suitable phonetics to represent any one of the gaseous elements (Fig. 3). Similarly, the radical "shui," for water, is used for the liquid elements (Fig. 4). The non-metallic solid elements make use of the radical "shih," meaning a stone, while the metallic elements use the radical "chin" indicating gold (Figs. 5, 6). In this way the Chinese written term for an element includes more information than does the English term as it reveals the physical state.

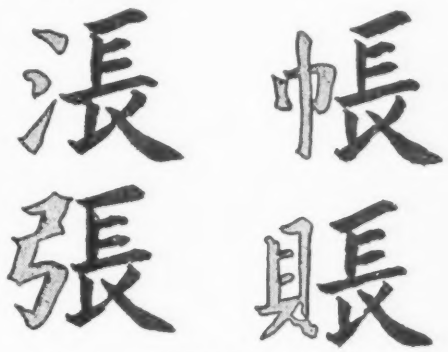

FIG. 2. CHINESE CHARACTERS
WRITTEN TO ILLUSTRATE THE COMMON PHONETICS COMBINED WITH DIFFERENT RADICALS.

FIG. 3. INERT GAS CHARACTERS
ILLUSTRATING THE COMMON "GAS" RADICAL, WHICH IS WRITTEN IN SOLID BLACK.

Wherever possible the sound of the Chinese character used approximates the sound of the chemical symbol. Masurium has the symbol "Ma," while the sound of the Chinese character is also "ma." Similarly, the sound for the lithium character is "li," for bismuth, "pi." To do this, it has been necessary in some cases to use very rare characters or even entirely new combinations of phonetics with the suitable radicals.

To illustrate the nomenclature for

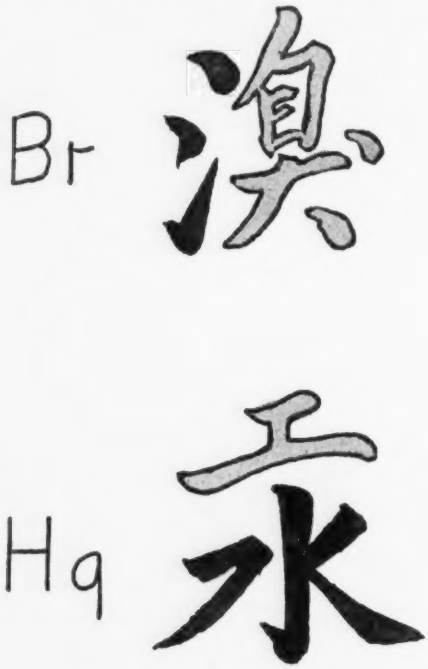

FIG. 4. LIQUID ELEMENT
CHARACTERS WITH THE "WATER" RADICAL WRITTEN IN SOLID BLACK IN ITS TWO FORMS.

inorganic compounds, a few examples have been selected and are presented as follows.

1. Oxides. A three-character expression has been adopted which literally translated reads, "oxygen change X" where X represents the other element. For silver oxide, we would say "oxygen change silver." The term joining the oxygen and silver is "hwa" which is part of the name of chemistry, as above explained.

2. Binary Compounds. Similar in form to that used for oxides. If the positive valence element has two valencies, the "ic" form is named as per the oxides. The "ous" form, as with ferrous chloride, is called "chlorine change inferior iron." However, another set of terms following the molecular formula as "three chlorine change iron" and "two chlorine change iron" are also in use. Both methods are combined in naming the numerous oxides of nitrogen or manganese.

3. Binary Compounds of Hydrogen. These are named as per other binary compounds, but if the aqueous solution is an acid, the translation is "hydrogen X acid" as for hydrochloric acid, "hydrogen chlorine acid."

4. Radicals. A distinction is made between a radical as such and when it carries an electric charge. The former is a "chi," while the latter condition is a "ken." This is made clear by the following illustration.

NH_2	"an" (special short name for ammonia, character is written with the gas radical)
$-NH_2$	"an chi"
$=NH$	"inferior an chi"
NH_4^+	"an ken" (character here for "an" has the metallic radical)

5. Oxygen Containing Acids. The order of naming follows closely the English terminology. Sulfuric acid is "sulfur acid" while sulfates as lead sulfate are written "sulfur acid lead." For a series of acids various prefixes are used, as below.

HCl	hydrogen chlorine acid
HClO	secondary chlorine acid
$HClO_2$	inferior chlorine acid
$HClO_3$	chlorine acid
$HClO_4$	exceed chlorine acid

Hydrochloric acid is included in this example to illustrate the difference in

names between the "ic" acids containing or not containing oxygen.

6. Hydroxides. Since the hydroxide group is called "hydrogen-oxygen" the term used, for instance, with sodium hydroxide is "hydrogen-oxygen change sodium." The term as expressed in this literal translation sounds clumsy and awkward, but it must be remembered, as was pointed out above, that Chinese is monosyllabic, and hence this expression has only four syllables in Chinese and is shorter than the English term.

7. Salts. The three types are written as below.

normal	lead sulfate	sulfur acid lead
acid	sodium bicarbonate	carbon acid hydrogen sodium or acid property carbon acid sodium
basic	basic lead nitrate	hydrogen-oxygen change saltpetre acid lead[5] or alkali property saltpetre acid lead

If there is more than one acid or basic salt, it is expressed as shown by this illustration.

Na_2HPO_4 phosphorus acid hydrogen two sodium
NaH_2PO_4 phosphorus acid two hydrogen sodium

Organic terms are not discussed in this paper since they have not been used to the same extent as are those of inorganic chemistry. This is due to their greater complexity and the comparatively few organic chemistry text or reference books written in Chinese. Hence organic compounds, save the commoner ones, are usually called by their foreign name (usually English).[6]

From the above discussion and illustrations it is clear that the Chinese language lends itself remarkably well to the creation of a chemical nomenclature. Since this development is quite recent, it has been able to profit by the experience of chemists elsewhere and the universal agreement now reached about the significance of general chemical terms. This, combined with the ideographic nature of the language, its clearness and simplicity of grammar, has resulted in a highly satisfactory nomenclature. At present, in certain branches where progress is proceeding rapidly, the temporary use of foreign terms is unavoidable. But as soon as such terms have been given a standard meaning, they can be readily included by the extension of the present system.

FIG. 5. CHINESE CHARACTERS FOR NON-METALLIC SOLID ELEMENTS WRITTEN TO ILLUSTRATE THE COMMON "STONE" RADICAL.

The author wishes to take this opportunity of thanking Miss H. Y. Liao and Mr. H. T. Chiang for their help in preparing this article.

FIG. 6. METALLIC ELEMENT CHARACTERS WITH THE COMMON "GOLD" RADICAL.

[5] Nitric acid is called saltpetre acid rather than nitrogen acid as a concession to common usage.

[6] It is interesting that of the 25 papers published in the *Journal of the Chinese Chemical Society* for 1941 (vol. 7), 23 are written in English and 2 are in German. Papers written in Chinese are not accepted.

SCIENTISTS AND MACHINERY OF THE STATE

By Dr. CHARLES E. KELLOGG

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As soon as the enormous social implication of science in a modern state is admitted, the great importance of symmetry in science is realized. To be successful, democracy must deal with many problems and many aspects, all relevant aspects, of each problem, because emphasis is placed upon the welfare of the whole group in terms of individual values and opportunities, not alone upon progress or efficiency in some special sphere or upon the material power of the state. In fact, the nearer the democratic state approaches perfection, the more its citizens become citizens of the world. As the individual finds his welfare related to that of his community, and the community to the state, so he finds the welfare of citizens in one state dependent upon the well-being of those in other states.

Thus in the democratic state problems must be conceived in relationship to this total problem, not just the problem of some one science or of some one specialist striving, perhaps, to achieve what he regards as a well-rounded program in terms of his special field. Certainly the scientist is after truth—wherever it is and wherever it leads, but with proper regard to its relevancy.

The achievement of this essential symmetry raises great problems of coordination. This is really another word for planning or for the development of proper balance. Frequently, very frequently, the coordination has been so difficult, that the problem has been "cut-down" or over-simplified, and then "solved," but, of course, the real problem remained where it was.

Since the problem of coordination is so closely related to the task of administration, the two have often been identified. Some go so far as to say that the task of administration is largely one of securing essential cooperation and coordination. Although this view simplifies the problem in terms of simple and customary administrative procedures it is scarcely acceptable. Coordination and administration are overlapping functions, and related functions, but they are by no means identical. As the rapidly growing need for coordination has been realized there has been a perfectly natural, but unfortunate, attempt to solve the problem and harmonize the needs in accordance with older existing patterns of organization—an attempt to fit the problem to the existing, familiar administrative techniques. Less attention has been given to the kind of organization needed to accommodate an attack on the problems.

The existing kinds of administration, with detailed organization, is likely to segregate scientists according to subject matter. Since many problems, especially those of broad significance, require the attention of scientists in several organizational groups, symmetrical programs in either research or in the application of scientific principles are often difficult to arrange. Individual groups are likely to over-simplify problems, vertically, in terms of their particular universe, experience, and techniques; although, of course, not necessarily, since many of the broadest thinkers are also identified prominently with some particular field of science.

Some have suggested a similar kind of organization, but with subdivisions according to problems, rather than according to skills or branches of knowl-

edge. This method leads to a different kind of over-simplification, but one just as serious, because all important problems overlap with others and the identification of a region, a group of people, or any single activity in society with some one problem is very likely to lead to over-emphasis and disharmony. In addition, this kind of organization leads to great duplication in research, since the results of fundamental researches are often essential to many problems. Further, intimate association with workers in the same field is as important to the researcher as association with workers in different fields.

An important development has been the establishment of coordinating groups —groups whose function it is to bring people with different points of view and different skills together for the consideration of problems. Likely some additional developments in this direction may be expected. As yet, the relationship of scientists to these groups and to this effort has not been clearly conceived, and their participation not very effective. Partly this is due to a lack of interest, and a shirking of broader responsibilities that so often accompanies specialization. But at the same time the scientist is often unwelcome to these groups, if he brings his scientific method with him. He sees too many sides of a problem, often objects to the simple solution, often refers to facts and principles.

Frequently the coordinator or coordinating groups undertake to define the problem and then tell the scientist his function and how he shall use his techniques in helping develop a solution. If the coordinator is well-informed in the particular field of the scientist, all may go smoothly. But usually he is not well informed, at least not in all fields, and oftentimes he is not trained in any field of science, or even familiar with the nature of the scientific method. Under such conditions the scientist, even the socially aware scientist who is convinced of the need for coordination and planning, finds himself in an impossible position. If he cooperates in the program already outlined or if he undertakes the problem as defined, he may feel almost certain that failure and waste are inevitable. This difficulty cannot be avoided by "voting in committees" where members are of widely different competence. Such voting is not entirely democratic because it is assumed, unconsciously, in the democratic processes, that those voting on a proposal are, theoretically at least, of approximately equal competence as far as the particular proposal is concerned.

In democratic coordination the extremes of autocracy or anarchy must be avoided. Scientists must and will insist upon a voice in the identification and definition of the problems. This is the first and most important essential. There must be reasonable agreement upon the problem and a common understanding of the objectives in both research and the application of scientific principles. Then in the area of his special competence, the scientist must determine how his skills and techniques can be used to best advantage in helping to solve the common problem. Each scientist becomes then, in effect, a coordinator, one of a group whose members have similar competence but in different fields. In this way the extremes of vertical and horizontal over-simplification can be avoided and the essential freedom for scientific inquiry preserved.

For successful planning the scientist must be socially aware, must realize his responsibilities and those of others; and he must refuse to accept a choice between broad thinking and specialization, or between theoretical soundness and practical utility.[1] The scientist who cooper-

[1] Of course, a proposal can be theoretically sound in *one* universe, in one situation, and impractical in *another*, but if practically sound in one it is also theoretically sound, even if the reasons are not clear to everyone.

ates in a preconceived program that he is sure to be unsound may gain a politically useful reputation as a "good cooperator" but he is disloyal to his responsibilities if he remains inarticulate in the democratic state.

Through cooperative study and planning, symmetry in science must be achieved if it is to realize its potentialities for use in a democracy. The maintenance of symmetry is a continual problem. In its simplest form: How shall the scientist select the problems on which he will work? Or stated in administrative terms: How shall the administrators or governing bodies establish priorities for research projects? Certainly individual specialists cannot go along entirely on their own, nor can "fields" be allotted equal funds.

First, there must be some broad understanding of the needs of the people—people as a whole, and of smaller groups, say farmers, workers, tenants, school children, investors, folk in the Great Plains, and other overlapping groups. These must be understood in relation to one another, to general and local economic and social forces, and to the environment. In planning agricultural research, for example, a first question is, what are the limiting factors—what are the things that are preventing our farm people from realizing a fuller life based upon adequate income, health, education, and the other values that must be recognized? Constantly agricultural scientists must be examining, and reexamining the whole field of agriculture and the problems developing on farms if they are to keep their research and their science symmetrical in respect to its function. The same is true in other fields, large and small, with due account taken of their many overlapping relationships. This need for dynamic symmetry extends to fundamental research as well as to that dealing with the application of fundamental principles. If we take a wider view of society as a whole, this kind of examination, by scientists, should extend throughout our culture.

This development of symmetry is a process that has no end—a continuing process, changing to meet new conditions, like the governing process. It isn't like the planning process for a building that precedes a definite period of construction. While planning is going on, people are living, working, and developing new or different things and ideas. In a democracy there can be no blueprinting of a master plan, and postponing separate actions until the "plan" is drawn. Rather planning in a democracy is a dynamic process of bringing into harmony a whole group of processes, through the use of knowledge, to make possible growth and opportunity for individuals. These separate processes in the world are moving rapidly. Although they can't be stopped, they need to be directed and brought into dynamic harmony, while there is time.

The Scientist and Decision

Scientists have a heavy responsibility in a democratic state for discovering and anticipating problems. All citizens have this responsibility—it is one of the duties of citizenship—but scientists who are socially aware have an especially useful rôle to play. As processes develop and change, they must be guided and directed if serious strains in the social order are to be avoided. In our country, too, with such far-reaching differences in environmental conditions from place to place, corresponding differences in social organization must be expected. Cultural uniformity in the United States would be disastrous to many folk. Through a proper balance between national solidarity and local autonomy, essential variations will be preserved, thus adding variety to the culture and strength to the state.

Scientists have the second responsi-

bility of clarifying and examining problems patiently and accurately, but without over-simplification, either vertically in terms of a single discipline or horizontally in terms of superficial generalities. Coordination must be arranged for problems requiring skills in several fields of competence to utilize, not reject, the most detailed knowledge and most refined principles. Above all, scientists must demonstrate the use of the scientific method, the greatest defensive weapon against the slogan, against the totality of a single idea.

As problems arise, decisions in respect to them must be made. Even a decision to do nothing may be just as significant and far-reaching as a decision to do something. In a democratic state the making of decisions is a widely diffused responsibility. Many are made by private persons and groups. The major decisions may be said to be made by the people directly, by their elected representatives, or by the elected administrators or their subordinates. There are, of course, many exceptions. Certain decisions taken by the governing board of a large corporation or trade union may appear to be far more important to the lives of a great many people than most of the decisions made in some elected governing bodies. But the private citizen, the corporation, or the trade union can only make decisions within a frame of reference laid down by law. Similar restrictions of law and tradition apply to all officials of government in the democratic state, although orderly processes are provided for removing or changing these restrictions and an exercise of the ultimate sovereignty of the state.

There are a great many decisions to be made at several levels of government. Presumably these are made in the best interests of the whole people, considering present and future needs, not in the restricted interest of some one group "representing" laborers, farmers, consumers, business men, or producers, or a special industry, section, trade, profession, or class. In a democracy, one of the greatest tasks of statesmen and of government is to reconcile differences among such groups, with due regard to the needs and welfare of individuals, minorities, and the majority. In the whole process of arriving at decisions, through investigation, evaluation, discussion, and compromise, there are many overlapping stages, both inside and outside the government. Scientists have an important rôle, not a dominating or governing rôle, yet one so important that the modern state can not survive without them.

We might take one problem just as an example—the control of soil erosion. A moment's reflection discloses that this problem is partly included in the wider problem of soil use, in conservation, in flood control, in irrigation, in the development of electric power, in forestry, in agriculture, and in other problems. It is more important in some regions than others. It is related to the social philosophy of individuals and groups regarding the soil. In other words, it is a problem that overlaps many others of equal, less, or greater importance, and cannot possibly be solved without regard to them. Nor is it new. Nor is there a solution to be adopted, once and for all.

Many citizens have been calling attention to this problem. Among these were scientists who studied soils, sought out the laws of their genesis and their changing relationships to plants and land-use practices. They studied the causes of erosion and its effects, and how it might be avoided. These studies are being continued by economists, geologists, engineers, agronomists, and many others beside soil scientists.

A few of these scientists were attached to national institutions of government, many were in state research stations,

while others worked as private citizens or in private institutions. Many recommendations were developed and carried out, but the problem seemed to call for special action by the social group—the government. Their efforts and discussions, as well as those of others brought the matter to the attention of other citizens, including elected officials and legislators.

These representatives decided to do something about the problem. In this decision itself the scientist is primarily a citizen. His original task was one of anticipating and clarifying the problem. But the decision of doing something about it involves competition with many other problems outside of his special field of competence. Such things as national defense, public health, education, maintenance of employment, and a balanced price structure, for example, to mention a few, many of which are of even more vital concern now, compete for appropriations. Thus this first decision to do something about it is made in a very broad frame of reference, or should be in a democracy.

After this general decision come others. How vital is the problem in relation to others? And how much effort should be directed to this one? How can soil erosion be controlled? Should the problem be attacked directly, or is it more an indication, a symptom, of some other problems?

Immediately, the thoughtful legislator and administrator can see that there are many ways toward a solution of the problem, and that several activities may contribute. Research for the development of new farm practices as applied to particular soil types, together with a wider dissemination of existing and new knowledge, in an educational program for farmers and other land users, is one way. This program is very flexible and might include farm or community demonstrations. As another approach, governmental agencies can be supplied funds for doing the work on the land with hired personnel. This can be done through central agencies or through grant-in-aid to local governments. Land-users may be given much or little responsibility in deciding what is to be done and in doing it. Again land-users may be paid subsidies for good practices, or they may be subject to penalties for poor ones. Local districts may be established as new agencies of government, or existing governmental agencies may be utilized.

These are a few of the alternatives. Here again scientists have a responsibility. They can predict, better perhaps than other citizens, the relative effectiveness of these different methods, their cost, and the administrative difficulties involved. That is, socially aware scientists who have kept their science symmetrical can. Having done this accurately and carefully, it is again not up to them as scientists to make the final decisions regarding which method or combination of methods shall be followed.

These decisions must take account of citizen opinion and how the several alternatives may influence other programs in agriculture, forestry, conservation, and flood control, other important objectives, and other values. The administrator who decides, or helps decide, may be a person with scientific training, may possess scientific knowledge, but it is not primarily in his capacity as a scientist, in the sense of an expert, that he exercises this judgment, but rather in his capacity as a citizen, with special responsibilities in the government of a democratic state.

It is thus through the use of scientific principles and the scientific method that social policy may be formulated and followed by action in a democratic state. Without using science to the limit and without arriving at decisions through a process that insures broad consideration,

and with speed where speed is essential, the inconsistencies in our culture will become sharpened and the cracks in the social organism will be widened. Especially now there is much work to be done to develop a more adequate use of science, while there is time.

Science and Liberalism

Broadly speaking, this discussion has been pointed toward a closer fusion of science and liberalism. Both concepts have a great deal in common. The scientific thinker stands midway between the dogmatist who entertains no doubts at all about the validity of his views and the extreme skeptic who believes nothing. To the scientist truth is a matter of greater or lesser probability. The liberal thinker stands midway between the extreme conservative who holds strictly to the status quo and the extreme radical who sees little or no good in the present. Democracy is the institutional expression of liberalism, midway between total authoritarianism and anarchy. In one sense, these three concepts—science, liberalism, and democracy—are relatively fixed, as far as conceptual ideals are concerned; yet in respect to the real world of things, ideas, purposes, actions, and processes, they are dynamic, changing concepts.

Liberalism in a democracy implies liberalism in ideas of morals, justice, art, and science. Science is concerned primarily with the relationship of facts to facts—how nature behaves, including man himself as a part of nature. The evaluation of the facts and principles of science in terms of social values can not be accomplished within the field of science alone, but only in the wide cultural atmosphere of all human ideas and values. Science and liberalism are mutually essential to one another. Without facts and an understanding of their relevancy, liberalism becomes empty, ineffectual, and futile; and without freedom for expression and criticism, for trial, error, and correction, science decays.

The American democracy was developed out of the same spirit of liberalism and freedom of thought that nourished science and laid the foundation for its modern development. Yet the early pattern of democracy was conceived when science was only beginning and before its material results became so important. Since that time, science has been accepted gradually and unevenly in modern society. The older forms and expressions of democracy are even used to support prejudices against changes that are seen, from the facts disclosed by science, to be essential for democracy. Many ideas that were liberal or scientific at the time the principles of American democracy were committed to paper 150 years ago, are not so regarded to-day, although the fundamental objectives of democracy and the principles of the scientific method have changed but little.

Some have confused conflicts between some particular *form* of democracy and certain principles of science, with a general conflict between the two concepts. They differ, and they overlap; but each supports the other. Yet in practice there are conflicts in modern democratic states that threaten their very existence, conflicts that can be resolved through the application of the scientific method in a steady framework of liberalism.

Liberalism, like science, must be symmetrical for effectiveness. A burning heart, filled with emotional sympathy for troubled people, is not enough. The liberal who avoids the task of informing himself can not expect to accomplish much. No man can fairly call himself a supporter of democracy who avoids this task, where opportunities are available. Liberalism without science becomes a sloppy sentimentalism. It expresses itself in whimpering or shouting

where calm thought and objectivity might be successful.

There is a failure to distinguish between charity and opportunity, between the lazy and the unemployed, between freedom and license, between carelessness and miscalculation, between privilege and responsibility, and between failures of the individual and failures of the state. Even the "good" man must sometimes fertilize his corn, spray his fruit trees, insure his house, and discipline his children.

Science without liberalism leads to efficiency conceived in narrow, materialistic terms—but an efficiency coldly silent about human values and ultimate goals for either the individual or society. It leads to a philosophy of survival of the strongest and the luckiest. In the commercial field, for example, because the housewife or farmer fail to judge the worth of a machine they legally buy, they must be penalized severely. Even though good becomes what is practical, the practical is measurable in physical terms. Art becomes decorative rather than inspirational. Man serves the machines, lives for the gadgets that were to serve him. Such a philosophy of material efficiency leads to suppression of those flights of fancy that gave it birth. The inventor's machine finally destroys the free spirits from whence his knowledge came.

Science without liberalism would lead us quickly to disaster, while liberalism without science might bring us more slowly to decay. Given the two concepts, dominant together, our people can find strength and happiness. Scientists have a large responsibility to help bring together the principles of science and those of democracy—to revitalize democracy as a dynamic pattern of social organization within which all may find opportunity and justice. Up to now they have scarcely taken the trouble. A great deal depends upon whether they do so in the future while there is time.

UTOPIAN DELUSIONS

To some who view the present chaos in the light of the follies of the last twenty years no small measure of blame must be laid at the door of the prevalent Utopian philosophy. One has only to recall the slogan, "war to end war" and the famous pact to outlaw war to illustrate the point. Surely the history of the United States from 1917 to 1941 shows the Utopian philosophy may defeat the very movements it would foster. Dreams based on a misconception of a total situation are bound to produce a secret reaction. When impossible ideals are set before men's minds, no harvests except bitter disillusionment and cynicism can be expected.

The danger exists again to-day. We are fighting to defend human liberty and render secure the American way of life. We desire to prevent the recurrence of a devastating world-wide struggle every generation. We want and expect to have the United States a better place to live in when the war is over. Limited objectives we must set. But let us proceed cautiously in painting too rosy a picture of the world or even the United States after the war is over. To my mind, the Utopians who foresee the future in terms of a world made perfect by technology and the applied social sciences, or those who believe in a complete spiritual regeneration of a majority of men are equally mistaken.

The facts of history and of human nature to me speak of a universe constructed on totally different principles. The problem of evil seems to be ever present as the air we breathe. Why this should be, I do not pretend to know; nor do I believe that man will ever fully understand, though he must never cease to try. In terms of my faith, it is unthinkable to say, as some have said, that men died in vain in certain wars because the proclaimed objective was never won. To me, whether a man lives or dies in vain can never be measured by the collective activity of his fellows, never by the fruits of war or peace. It can be measured only by the way he faces his own problems, by the success or failure of the inner conflict within his soul. And of this no one may know save God.—*Baccalaureate Sermon; James B. Conant, President of Harvard University.*

BOOKS ON SCIENCE FOR LAYMEN

AIRPLANES—PAST AND PRESENT[1]

WHETHER the airplane is considered a blessing or a curse to the human race, its ever-increasing influence in human affairs can not be denied. The coming of the present war brought the airplane as a harbinger of suffering and death to the civilian population, to innocent women and children, and made war as never before total war. To-day for us the airplane assumes the aspect of the major offensive weapon by means of which victory is ultimately to be achieved. Bigger, faster and better, they roll from the long assembly lines to travel to the far corners of the world.

When one inspects the intricate assembly of mechanisms and structure in a modern long-range bomber, he marvels at the ingenuity and skill of the mind that comprehends the functions and methods of operation of the parts. The intelligence required to create it seems beyond the power of men. As with most scientific achievements, this appraisal is based on an illusion, for the airplane in its present form is a creation not of one mind but of many minds. It has roots in the past, and its present state of development can be appreciated only by studying its history, its step-by-step development from a mere dream to its present stature.

Mr. Black's non-technical narrative account of the development of the balloon, airship and airplane gives the historical background required for appreciating these products of painstaking scientific investigation and experiment. A careful reader of his book will come to comprehend that the airplane was not invented full-fledged by any one individual, and that its continued improvement rests on the efforts of many scientists and engineers in different fields working together.

Mr. Black tells of the countless centuries of mythology preceding the period of engineering and scientific development, of Daedalus and Icarus, of Roger Bacon, Da Vinci and De Lana, of the discovery of hydrogen in 1766, of the Montgolfiers' hot-air balloon and Charles' hydrogen balloon in 1783, of the development of the rigid airship. Interspersed with these accounts are descriptions of Cayley's experiments, of Henson's "Ariel" and Stringfellow's models, the whole occupying three chapters of the twenty-two and twenty-eight of the 267 pages in the book. This brief summary of three chapters illustrates the general method of treatment. The treatment is not encyclopedic but accomplishes the author's purpose of creating mental pictures of each period.

The appraisal of the work of Langley and of the Wright brothers is unusually accurate for a popular account. Langley is included with Maxim and Clement Ader as the three who nearly succeeded, and the accomplishment of the Wright brothers forms the subject of Chapter VI under the heading "Mechanical Flight at Last." Good judgment has been used in the accounts of other controversial matters such as the patent suits, the production scandals of World War I and the warship bombing controversy.

The book covers the period down to the beginning of World War II. Included within its pages are numerous accounts of beneficial contributions to human happiness and welfare. Like all physical creations of science and technology, the airplane in itself is neither good nor evil and has no moral attributes. It is a tool which can be used by human intelligence for good or evil purposes and Mr. Black's book is a faithful record of the manifold purposes for which it has been used in the past from "ballyhoo" at county fairs to fast transport of goods and passengers.

HUGH L. DRYDEN

[1] *The Story of Flying.* A. Black. Illustrated. xxii + 267 pp. $2.75. April, 1940. McGraw-Hill Book Company.

THE PHILOSOPHY OF ALFRED NORTH WHITEHEAD[1]

THE volume is the third of a unique series entitled "The Library of Living Philosophers," following after two similar publications on John Dewey and George Santayana. Noteworthy indeed is the purpose of the editor of the series; it is to select philosophers of competence with interests akin to those of the great thinker whose works are under discussion, and assign to them the task of critique and query while the venerable subject is living and capable of answering his critics. The results are then collected in a single volume which is to be handed to posterity, an authentic document on the thought of a great philosopher. In the present instance, the execution of the plan almost equals its brilliant conception; the shortcomings are not the fault of editor or authors: they lie in the regrettable fact that a serious illness prevented Professor Whitehead from making specific replies to his critics.

The book contains, first of all, fourteen pages of autobiographical notes by Whitehead, simple remarks which by their candor and factualness strike at the heart of the reader. Then follow eighteen scholarly articles by V. Lowe, W. V. Quine, F. S. C. Northrop, E. B. McGilvary, J. Needham, P. Hughes, W. M. Urban, A. D. Ritschie, A. E. Murphy, W. E. Hocking, R. W. Sellars, J. Goheen, B. Morris, J. S. Bixler, C. Hartshorne, P. A. Schilpp, H. W. Holmes and John Dewey. None of them is a mere résumé of Whitehead's philosophy; each brings forth new fundamental ideas suggested by the work of Whitehead, each questions earnestly the validity of some feature or other of his writings, each author endeavors to amalgamate Whitehead's views with his own. As one reads on, there grows in one's mind an acute regret that circumstances should have made impossible detailed answers to so imposing an array of significant and sympathetic questions. But the sense of frustration is at least partly destroyed when the reader finds, at the end of the volume, two summarizing articles from Whitehead's pen, the second of which will rank among the most memorable of his writings. They are entitled "Mathematics and the Good" and "Immortality." At the end there is a fairly complete bibliography of Whitehead's writings.

No specific reason need be offered for recommending a book on philosophy to scientists. But it does seem relevant to remark that Whitehead was, first of all, a scientist and that his philosophy is the sublimation of the experiences of an active and brilliant mathematician.

HENRY MARGENAU

[1] *The Philosophy of Alfred North Whitehead.* Paul A. Schilpp, editor. xviii + 745 pp. Illustrated. $4.00. 1941. Northwestern University Press.

CONDITIONED REFLEXES AND PSYCHIATRY[1]

THIS Volume II of Pavlov's work on conditioned reflexes adds sixteen chapters to Volume I, published in 1928. From Dr. Horsley Gantt's introduction we learn that the two volumes represent "the only complete collection of Pavlov's lectures on conditioned reflexes and psychiatry in any language." For this enrichment of the physiological and pathophysiological, psychological and psychopathological literature, scientific workers, particularly English-speaking scientific workers, owe a debt of gratitude to Dr. Gantt, translator, interpreter and exponent of Pavlov's work.

In the present volume Pavlov interprets psychological concepts, psychoneurotic and psychotic reactions in terms of conditioned reflexes. These are identified with what associative psychology calls association. Both, conditioned reflex and association, represent two aspects—physiological and psycho-

[1] *Conditioned Reflexes and Psychiatry.* Ivan Petrovitch Pavlov. Translated by W. H. Gantt. Illustrated. 199 pp. $4.00. May, 1941. International Publishers.

logical—of the same phenomenon, that is, perceptions and reactions associated with coincidental, though under the circumstances unessential factors, may be spontaneously evoked by one or more of the incidental factors. The fact that a well-established conditioned reaction may serve as an unconditioned stimulus for the formation of a new conditioned reaction makes it still more obvious that the identity of the concepts of association and conditioned reflex is complete. In one of his last writings, if not the last, Pavlov expressed his pleasure at the recognition by associative psychologists that conditioned reflexes provide a firm basis for associative psychology.

In accordance with the classical subdivision of the anatomy and physiology of the C.N.S., Pavlov speaks of: (1) *The lower nervous activities, i.e.*, activities necessary to maintain life and carried out by the vegetative subcortical centers. These vegetative functions are called *unconditioned* and stimuli provoking them are *unconditioned* stimuli. (2) *The higher nervous activities*—controlling behavior—have their seat in the cerebral hemispheres. These are *conditioned reactions* caused by *conditioned stimuli.*

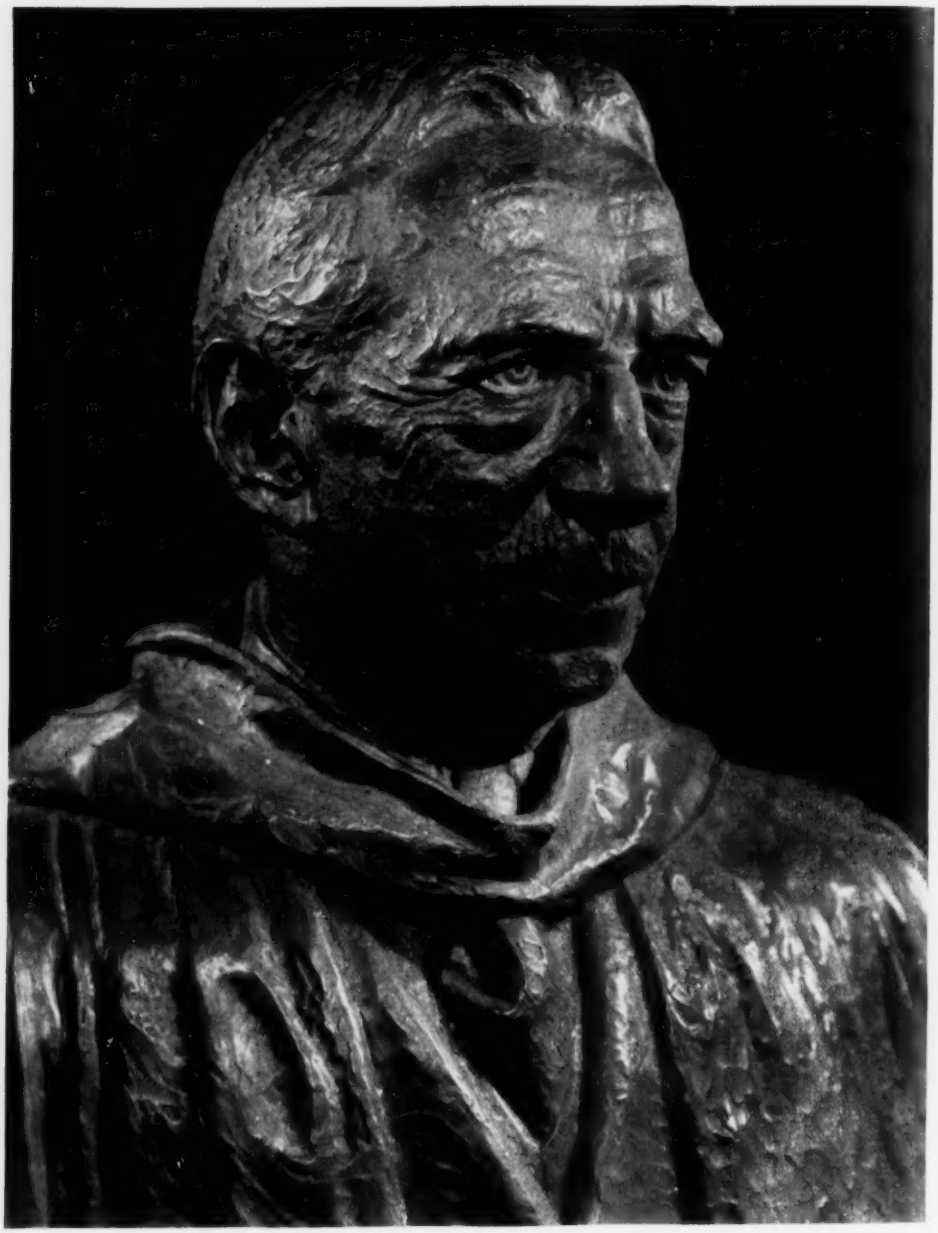
The fundamental physiological processes of the whole C.N.S. system are those responding to excitation and inhibition, both of which under certain conditions may be provoked by the same stimuli; and both of which are subjected to the laws of irradiation, concentration and interaction.

With these basic physiological notions, supplemented by the recognition of the role of constitutional endowment and by very accurate and abundant observations in animal studies, Pavlov had tried to throw light on the mechanism of human neurotic and psychotic reactions. The common denominator in various abnormal mental reactions lies in impairment of the normal balance between nervous excitation and inhibition. Thus, the main factors causing neuroses are: Too strong or too complex stimuli; predominance of inhibitory processes; collision between excitation and inhibition processes. In schizophrenic conditions the primary trouble lies in the weakness of the C.N.S., particularly of the cortex. The weak nervous system reacts to environmental difficulties readily with fatigue. The organism protects itself against undue or excessive fatigue in making appeal to the inhibitory processes of the cerebral hemispheres; when sufficiently inhibited, the cortex loses control over the subcortical function. The progression of inhibition ultimately culminates in a chronic state of hypnosis. Thus, Pavlov reaches the conclusion that "schizophrenia in certain variations and phases actually represents chronic hypnosis."

It appears highly doubtful either that Pavlov's physiological interpretations of psychological and psychopathological phenomena are illuminating at the present state of our knowledge or that they are paving the way for further fruitful investigations. But the perfect experimenter, as Pavlov was, unintentionally teaches us a great lesson: and that is that dogmatic adherence to one concept in trying to understand complex and heterogeneous phenomena is conducive to sterile speculation. What Pavlov has failed to see is that analysis pushed to the extreme does not necessarily help to understand the analyzed "whole," which, on the other hand, lends itself for studies with methods and procedures—other, than laboratory physiological ones—respecting the integrated function of the "whole."

These critical remarks are not intended to convey the impression that the book is not worthwhile reading. The contrary is the reviewer's opinion. Gantt's Introduction offers a particularly valuable historical survey of the last few years of life of Pavlov. It also presents a review full of sound interpretations and constructive criticism of the essentials of Pavlov's life work.

S. KATZENELBOGEN



BRONZE BUST OF THE LATE HENRY FAIRFIELD OSBORN

UNVEILED AT CEREMONIES DEDICATING THE NEW NORTH AMERICAN MAMMAL HALL OF THE AMERICAN MUSEUM OF NATURAL HISTORY OF WHICH OSBORN WAS PRESIDENT FROM 1908 UNTIL HIS DEATH IN 1935. HE WAS ELECTED PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE IN 1913, AND WAS A MEMBER OF THE NATIONAL ACADEMY OF SCIENCES AND NUMEROUS OTHER AMERICAN AND FOREIGN SCIENTIFIC SOCIETIES. THE BUST IS THE WORK OF JOY FLINCH BUBA.

THE PROGRESS OF SCIENCE

FRANKLIN MEDALISTS FOR 1942

Two men whose achievements have contributed notably to important war industries were chosen as the recipients of the Franklin Medal this year. At the Medal Day exercises of the Franklin Institute in Philadelphia the medals were presented by Charles S. Redding, president of the institute, to Paul Dyer Merica and Jerome Clarke Hunsaker.

Dr. Merica is a metallurgist of world-wide distinction. He received the degree of doctor of philosophy from the University of Berlin, and shortly afterwards joined the staff of the Bureau of Standards in the newly created division of metallurgy under Dr. George K. Burgess.

Shortly after the last war Dr. A. Wilm had developed duralumin by melting suitable mixtures of copper and aluminum. This alloy when quenched from a temperature of about 500° C and tested without delay, showed only moderate hardness and strength. But after standing a few days at room temperature, the same tests revealed that hardness, strength and ductility increased from 30 to 50 per cent. This strange behavior of duralumin attracted Dr. Merica's attention. His subsequent researches into its problems resulted in his advancing a daring hypothesis concerning the process of hardening after quenching.

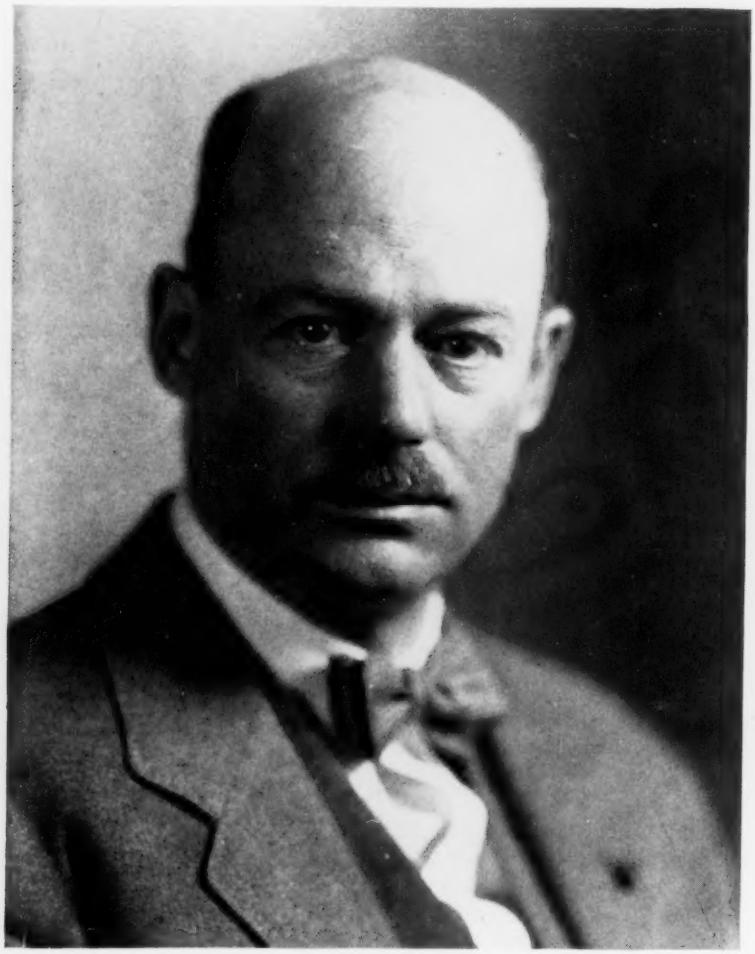
The opinion prevailing at the time was that the hardness condition of an alloy was that of its solid solution. Dr. Merica suggested that the hardness of the solid solution might be increased by a partial decomposition. He concluded that the cause of the increased hardness of duralumin brought about by aging at room temperature was the partial decomposition of the alloy resulting in the precipitation of minute particles of the binary compound $CuAl_2$. During the process of aging, particles of the binary compound extricate themselves from the solid solution and attain positions such that the internal stresses upon them are in equilibrium, hence they are hard to dislodge when mechanical stresses are applied to the whole mass, thereby giving to it the properties of strength and hardness.

He continued his work on other aluminum alloys and extended his field of research to include the alloys of nickel and cast iron. He also devised a method of heat treatment which improved many alloys not regarded as capable of improvement by heat treatment. His success in adapting many alloys to commercial uses has been quite as distinctive as his discovery of precipitation hardening.

Dr. Merica is the author of several books of recognized originality and merit upon metallurgical subjects. He is now vice-president of the International Nickel Company.

The second Franklin Medal of the year was awarded to Jerome Clarke Hunsaker, head of the department of mechanical engineering, Massachusetts Institute of Technology, and chairman of the National Advisory Committee for Aeronautics. After a brilliant career at the U. S. Naval Academy, Dr. Hunsaker was assigned to the Corps of Naval Construction and was sent by the Navy Department to the Massachusetts Institute of Technology, from which he graduated in 1912.

He spent the following year in Europe studying the dynamical stability of airplanes, paying particular attention to the technique of wind tunnel testing, at the National Physical Laboratory in London and at the Eiffel Laboratory in Paris. Upon his return to this country he convinced the authorities of the Massachusetts Institute of Technology of the importance of this new technique and personally superintended the construction of a wind tunnel. He then, at the age of 28, established the first college



DR. J. C. HUNSAKER

course in the United States devoted to aerodynamics and airplane design.

The Navy Department appointed him head of the Aircraft Division of the Bureau of Construction and Repair, and Dr. Hunsaker thus became responsible for the design, construction and procurement of naval aircraft during the first World War. It is interesting to note that he was one of the first to appreciate the usefulness of duralumin in the field of aeronautics at about the same time that Dr. Merica was developing his theory on precipitation hardening of this alloy.

Dr. Hunsaker has left an indelible impression upon the aeronautical science of the generation which has witnessed its greatest advances. His contributions to the science have been manifold and various. Some of his more noteworthy achievements have been the design of the NC type of flying boat (one of which made aviation history on its transatlantic flight in 1919); the design of the first large airship (the *Shenandoah*) made in this country; the development of launching catapults and arresting gear for deck landings on airplane carriers; the design of light planes for ser-

DR. PAUL D. MERICA

vice on carriers; the design of an air-cooled radial engine; and the development of a gas-proof fabric for airship construction.

In 1920 he was awarded the Navy Cross with the following citation:

For exceptionally meritorious service in a duty of great responsibility in charge of the Aircraft Division of the Bureau of Construction and Repair, in which position he showed ability unsurpassed in the United States as an aircraft designer as well as great organizing and executive ability in expanding and handling a large force. The successful development of naval aircraft was due largely to the ability and industry of this officer.

HENRY BUTLER ALLEN,
Secretary and Director
THE FRANKLIN INSTITUTE

MEETING OF THE SOUTHWESTERN DIVISION OF THE AMERICAN ASSOCIATION

Is it wise to hold scientific meetings during the duration of the war? The reasons given for abandoning them include the difficulty of automobile and railroad transportation resulting from rationing of cars, gasoline and tires, and

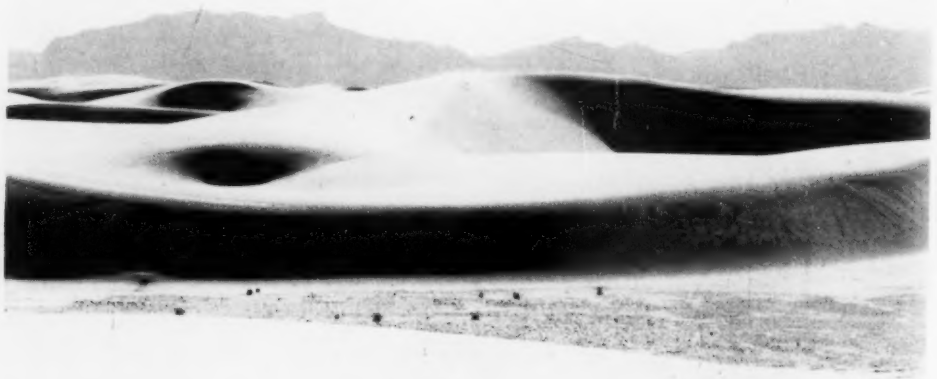
National Park Service

ADMINISTRATION BUILDING AT THE WHITE SANDS NATIONAL MONUMENT

THE VISITING SCIENTISTS HEARD TALKS ON THE WHITE SANDS IN THE PATIO OF THIS BUILDING.

the urgent need of space on railroads and airplanes for the transportation of troops and government employees. Some people argue that scientists are too busy with secret war work to take the time to attend meetings. Others say that the extra burdens placed on college teachers and industrial research workers make it impossible for them to carry on any but the most urgent scientific activities.

The recent meeting, April 28–30, of the Southwestern Division of the American Association for the Advancement of Science gave some interesting sidelights on the above question. Eighty-seven papers were presented in the fields of physical, biological, mathematical and social sciences in spite of the fact that the division has a membership of less than four hundred in the American Association. About 40 per cent. of the titles were presented by the faculty and students of the New Mexico State College of Agriculture and Mechanic Arts, which served as host institution. Some were presented by young men who had never had the opportunity of attending a large scientific meeting. They were



National Park Service

THE WHITE SANDS AND SAN ANDRES MOUNTAINS

THESE VAST SAND DUNES OF WHITE GYPSUM EXTEND OVER 600 SQUARE MILES.

not only thrilled by the occasion, but obtained valuable experience in the preparation and presentation of their work. There were papers having a more or less direct bearing on our war and post-war program and included such titles as "On the Anatomy of the Guayule," "Sales Tax in a Victory War Program" and "A Preliminary Examination of Some Proposals for World Reconstruction."

The men who are to-day engaged in semi- or non-war scientific work will to-

National Park Service

YUCCA IN BLOOM ON THE EDGE OF THE WHITE SANDS

morrow furnish the reserve from which our government and industries will draw their highly trained man power. This reserve must be kept intact by constant replacement. One conclusion which can be drawn from the above observations is that it is occasionally necessary to bring scientific meetings to scientists rather than scientists to meetings.

The meeting opened officially with an address of welcome by Dean Branson, acting president of the college in the absence of President Milton, who is on leave as an officer in the Chemical Warfare Service. The response was given by President Craig of the association. A great impetus to the problem of conservation was given in 1933 as the result of the selection of Aldo Leopold to give the fourth John Wesley Powell Lecture in Las Cruces on the occasion of the first Las Cruces meeting. Dr. Leopold discussed the general problem of soil erosion and its correction as related to the conservation of plant and animal life. Since that time the Southwestern Conservation League has been very active and has been largely guided by Dr. John D. Clark, professor of chemistry at the University of New Mexico. At the noon luncheon on Monday, Dr. Clark delivered a paper on "Conservation since 1933," in which he reviewed accomplishments since Dr. Leopold's visit.

Following the evening dinner sponsored by the American Association of University Professors and Sigma Xi, Dr. Donald D. Brand, of the University of New Mexico, spoke on "Observations on Certain South American Economies," in

HADLEY HALL
ON THE CAMPUS OF THE NEW MEXICO STATE COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

DR. H. P. MERA
NEWLY ELECTED PRESIDENT OF THE SOUTHWESTERN DIVISION OF THE ASSOCIATION; ARCHEOLOGIST, LABORATORY OF ANTHROPOLOGY, SANTA FE.

which he attempted to explain some of the causes of misunderstanding between the nations of the two continents. On Tuesday evening Howard W. Blakeslee, science editor of the Associated Press and joint winner of the Pulitzer prize in journalism in 1937, delivered the Thirteenth John Wesley Powell Memorial Lecture in the Branigan Memorial Library in Las Cruces, on the subject "Science Moves Ahead." These lectures were established in 1929 in honor of the noted explorer of the Grand Canyon. Under present arrangements the lecture is presented to the community in appreciation of its encouragement and support of the meeting. The person chosen to deliver the address is a distinguished scholar in his field, and is at liberty to speak on a topic of his own selection.

On Tuesday afternoon a caravan carrying seventy persons left Las Cruces for the "White Sands National Monument" near Alamogordo, New Mexico. The monument consists of vast "sand" dunes of snowy white gypsum covering an area of more than 600 square miles. Near the front of the sands, which advance from two to twenty feet per year, vegetation thrives, but back in the interior there is not a trace of vegetation to mar the dazzling white. Custodian Johnwill Faris welcomed the party, after which Dr. W. B. McDougall, of the Park Service, gave a talk on the "History and Development of White Sands National Monument" in the patio of the Administration Building. This was followed by a talk on "Gypsum on Tour" by Dr. S. B. Talmadge, professor of geology at the New Mexico College of Mines at Socorro. A concluding talk was given on "Some Biological Relations of the White Sands" by Dr. F. W. Emerson, professor of biology at the New Mexico Highlands University at Las Vegas. Dr. Emerson's talk was given

AERIAL VIEW OF THE NEW MEXICO STATE COLLEGE

after the party had been taken some distance out among the dunes, where he had the material for his discussion easily available. The caravan then proceeded to the barren interior, where nothing but the sands were visible. The scientists, with wives and children, amused themselves climbing the dunes and sliding down the steep fronts, and had no difficulty working up a good appetite for the delicious "chuck wagon supper" which was being prepared.

Wednesday noon a strictly Spanish luncheon was served at "La Posta" in Old Mesilla. Following the luncheon Dr. Fabian Garcia, director of the New Mexico Agricultural Experiment Station, told of many incidents of historical

FOSTER HALL, NEW MEXICO STATE COLLEGE

interest in connection with "La Posta," Old Mesilla and the "Billy the Kid Museum." This was followed by music and dancing by Spanish-American senors and senoritas in the patio of La Posta. Following the closing section meeting on Wednesday afternoon the U. S. Bureau of Plant Industry conducted a tour in which cotton, guayule and cactus were the principal topics of interest. The meeting came to a close officially with a banquet and the address "the Rôle of Spectrography in National Defense" by retiring President Wm. M. Craig, professor of chemistry at the Texas Technological College at Lubbock.

Persons remaining on Thursday were offered a choice of trips to the Jordana Experimental Ranges of the New Mexico College of Agriculture and Mechanic Arts and of the U. S. Forest Service, to the Organ Mountains to observe the native flora and fauna, to the newly discovered Conkling Cave at Bishop's Cap Mountain, or to the city of El Paso, Texas, and Juarez, Mexico.

At the annual business meeting, Dr. H. P. Mera, of the Laboratory of Anthropology at Santa Fe, was elected president, Professor F. H. Douglas, of the Denver Art Museum, was elected vice-president, and Drs. Wm. M. Craig and E. W. Haury were elected to serve on the executive council.

FRANK E. E. GERMANN,
Secretary-Treasurer

A SCIENTIFIC MEETING CANCELLED

A SUMMER meeting of the American Association for the Advancement of Science was scheduled to be held at the University of Michigan, at Ann Arbor, from June 22 to June 25. Programs were being organized by the sections of the association and by various of its affiliated societies until early in March, when it was suddenly announced that the meeting had been cancelled.

There was no reluctance on the part of the University of Michigan to act as host to the association. It had splendid facilities to offer. Its Wrackham building would have provided admirable headquarters; its many lecture halls, excellent meeting places; its dormitories, convenient living rooms. It is a great scientific center. Nearly all the leading scientists on its faculty are members of the association, and Dr. Malcolm H. Soule, chairman of the Hygienic Laboratory and professor of bacteriology, is secretary of the association's Section on Medical Sciences.

The association desired to meet at Ann Arbor. Not only is the University of Michigan a great institution, but it is within easy reach of the many endowed universities and colleges and other state universities of the Middle West. Moreover, Ann Arbor is near the center of a great manufacturing area in which there are numerous large industrial laboratories whose technical staffs include many members of the association. Yet the proposed meeting was cancelled.

The maturing plans of scientific societies and of scientists were set aside indirectly because of what was taking place in Europe, Asia, Africa and the East Indies and on the oceans. World events made it necessary for the university to change radically its academic schedule, to initiate early in June a three-term yearly program instead of two semesters with a long summer vacation. The term beginning in June will continue until the end of September; the next will promptly follow and continue, with a week's vacation at the Christmas holidays, until the end of January; and the third will extend from February until the close of May. Similar reorganizations of academic schedules and of courses are taking place all over the land.

These interruptions of the smooth flow of academic routine may be irritating,

but they are being made for serious purposes. Perhaps the usual distribution of time between periods of work and of vacation in universities has been based too largely on what would be most enjoyable to faculties and students rather than on what would be most useful to the institutions or to society. Perhaps, on the contrary, the drawing of scholars from the relative seclusion in which they have sought out and attempted to transmit to others the great achievements of the human mind will retard the progress of civilization. Evidently no simple statement can describe what is now transpiring in science and education and no one can foresee what the consequences will be.

It is clear, however, that educational institutions must now examine the whole subject of values as never before. Problems of the war are forcing them to do it. Already they are revising their objectives and their methods of attaining them. The problems that will follow the war will force them to reconsiderations of any conclusions they may reach at present, for what is advantageous is advantageous relative to an environment rather than in the abstract, and the environment then will be entirely different from what it has been in the past or is at present. It may well be that the conclusion will be reached that educational institutions have been coasting on the great momentum they acquired in the early decades of this century when technological applications of science produced great wealth and provided unparalleled leisure, without at the same time imposing the stern discipline of new ideals.

At the moment the scientists who were planning to attend the meeting of the association in Ann Arbor are disappointed, but the plans for the New York meeting beginning next December 28 are going steadily forward. It takes such minor irritations as the cancelling of a meeting to arouse men to note the changes that are going on in the world.

F. R. M.

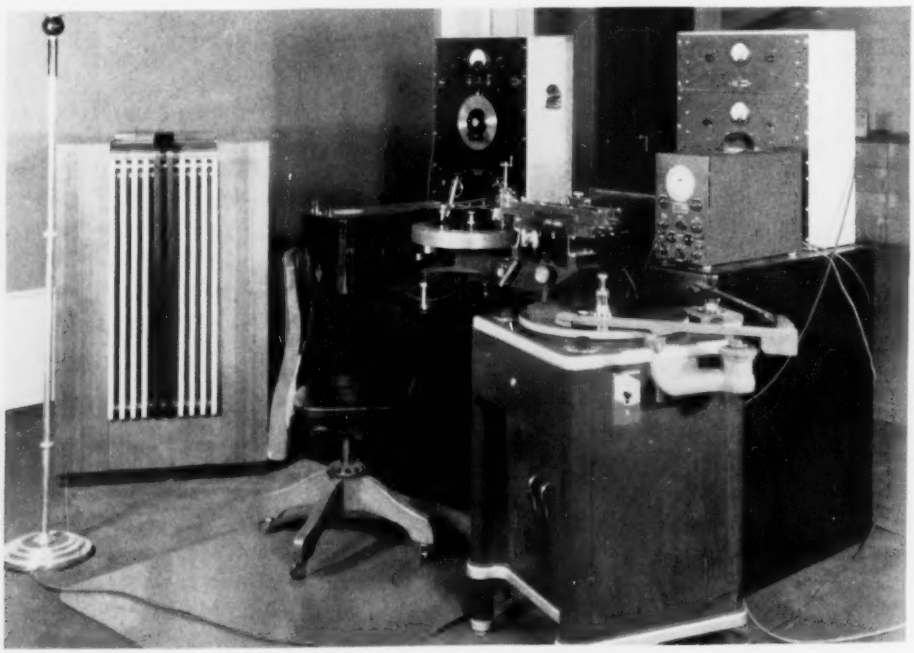
AMERICAN INDIAN SOUND RECORDINGS IN THE NATIONAL ARCHIVES

R. D. W. Connor, archivist of the United States, has announced the receipt of a gift of $30,000 by the National Archives Trust Fund Board, established by a recent Act of Congress. The gift is a contribution from Mr. and Mrs. Hall Clovis, to be used "for transferring the Smithsonian-Densmore Collection of American Indian sound recordings to a permanent base from which service copies can be made." Mr. and Mr. Clovis became interested in this undertaking through George W. Blodgett, eminent sculptor of Indian subjects and secretary of the National Gallery of the American Indian, of which Mrs. Clovis is vice-president, a national organization devoted to disseminating information on the American Indian and "presenting him, his arts, crafts and culture to the white man as a living creative force." The work will be done under the direction of John G. Bradley, the representative of that organization for the District of Columbia, and chief of the Division of Motion Pictures and Sound Recordings in the National Archives.

The Smithsonian-Densmore Collection, said to be the largest of its kind in existence, was transferred to the National Archives by the Smithsonian Institution in March, 1940. It comprises more than 3,000 items of religious, social and tribal music of 76 American Indian groups whose habitat extends from Alaska to Mexico. The recordings cover a period of over 40 years, the earliest date established being 1893. They were made for the most part by ethnologists and collaborators of the Bureau of American

FRONT VIEW OF THE NATIONAL ARCHIVES BUILDING
THE BUILDING WHICH HOUSES THE SMITHSONIAN-DENSMORE COLLECTION.

Ethnology in Indian camps and at Indian ceremonies. The greater number were made by Frances Densmore, American musicologist. Other collectors were John P. Harrington and John R. Swanton, at present members of the staff of



EQUIPMENT USED IN REPRODUCING COPIES OF INDIAN SONGS

the Bureau of American Ethnology; Alice Fletcher, assistant in American ethnology at the Peabody Museum, Harvard University; Francis La Flesche, son of an Omaha Indian chief and himself then a member of the staff of the Bureau of American Ethnology; Jesse W. Fewkes, the "Dean of American Archeologists"; Thurlow Lieurance, composer and musician, and others.

Inasmuch as the recordings are on perishable wax cylinders and are quite old, the importance of transferring them to a permanent base at this time is apparent. In prosecuting this work the National Archives will perpetuate and vitalize for posterity evidence of a significant culture rapidly fading from the American scene. Many songs in the collection are unique because their singers have died and the younger generation of the tribes does not know the beauty and wisdom of their ancestral ceremonies. In a few years it will be too late to save the creative work of the first Americans.

The titles of the songs in this collection illustrate the colorful aspects of Indian music, such as "A Song of Thanks for Food," "Song When a Pony is Given Away," and "Feasting the Scalps." Some of the Indian singers listed are Holding Eagle, Wounded Face, Old Dog, Wolf Chest, Bill Thunder and John Bearskin.

STORAGE EQUIPMENT
FOR DISC COPIES OF THE COLLECTION OF AMERICAN INDIAN SOUND RECORDINGS.

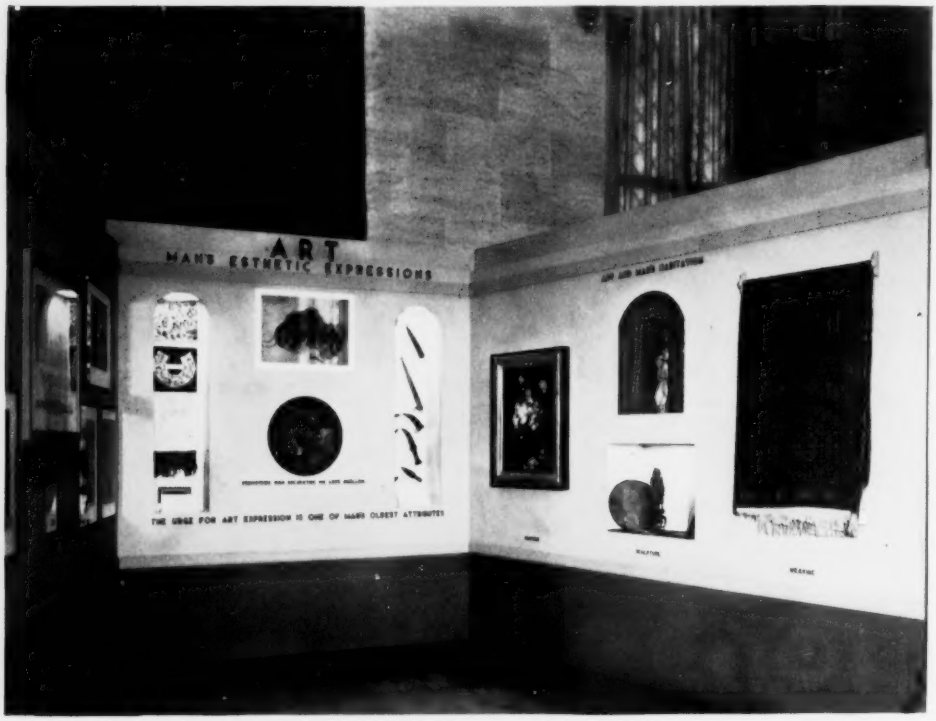
The transfer of these records to a permanent base will make them available to students of music, ethnology and anthropology, and to all others interested in the culture of the American Indian.

T. P.

ART ALCOVE IN THE INDEX EXHIBIT OF THE SMITHSONIAN INSTITUTION

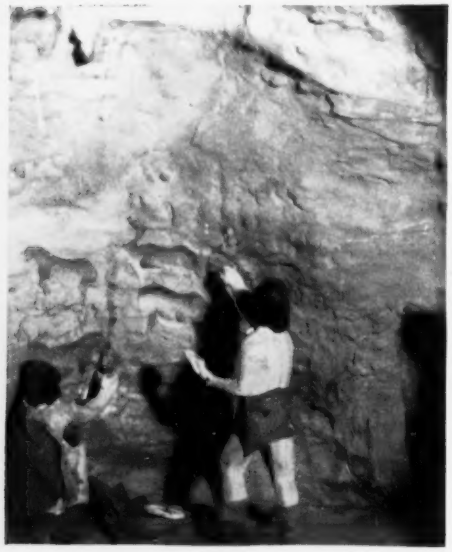
Although in the past year with the opening of the new National Gallery of Art the Smithsonian Institution has become a great art center, the field of art is modestly illustrated by one of the smaller alcoves in the Smithsonian Index Exhibit. Above and in the center wall is the leading caption—Art: Man's Esthetic Expression. Beneath this is a small round diorama showing prehistoric man painting pictures of animals on the walls of a cave in southern Spain, while a larger watercolor reproduction of one of the animals supplements and more clearly illustrates the theme of the group. These are flanked by two vertical sunken cases, one of decorated weapons and the other of textiles. These two cases serve to show that the urge to decorate has been applied to all of man's objects and materials, back to the earliest remains of human handiwork. The underlying statement for this wall is appropriately "The Urge for Art Expression is One of Man's Oldest Attributes."

The two larger side walls are devoted respectively to "Art and Man's Habitation," and "The Graphic Arts," the former having to do with decoration of man's structures, private and communal,



ART ALCOVE OF THE SMITHSONIAN INSTITUTION INDEX EXHIBIT

IN THE LEFT PANEL ARE EXAMPLES OF THE GRAPHIC ARTS—ETCHING, WOOD CUT, ENGRAVING, ILLUMINATED MANUSCRIPT, LITHOGRAPH, PHOTOMECHANICAL REPRODUCTION AND CHROMO LITHOGRAPH. IN THE CENTER PANEL ARE EXAMPLES OF PREHISTORIC, GRECIAN, MOHAMMEDAN AND OTHER ANCIENT KINDS OF ART. IN THE RIGHT PANEL ARE EXAMPLES OF PAINTING, SCULPTURE AND WEAVING.



CAVE DECORATION

A SECTION OF THE MODEL SET IN THE CENTER PANEL SHOWING PREHISTORIC MAN AT WORK.

the latter with decoration of messages and means of disseminating art by reproduction methods. In the former are shown, by specimens chosen not for their peculiar intrinsic importance but merely as illustrative types of their respective fields, the arts of painting, of sculpture, and of weaving. The art of architecture had to be omitted for reasons of space. On the opposite wall the development of the graphic arts is centered around an illuminated manuscript (in this instance a papal bull of the early Renaissance) flanked by examples of the main methods of engraving, lithography, etching and color reproduction. Such purely mechanical methods as photography are not included, although the Institution has large collections of such material and is fully aware of the growing place of art in manipulating photographic techniques. HERBERT FRIEDMANN